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ABSTRACT

The goals of the Educational Applications of Geographic Information Systems (EdGIS) Conference were to: showcase current applications of Geographic Information Systems (GIS), remote sensing, and other mapping software in pre-college education; develop a better understanding of the current state of the art in both GIS software and related curriculum development; prepare recommendations for further research and development in GIS; and promote public awareness and support for the educational uses of mapping software. Presentations include: (1) "An Introduction to GIS in Education" (Daniel Barstow); (2) "The Charge from the National Science Foundation" (Gerhard Salinger); (3) "Welcome from the National Geographic Society" (George Peterson); (4) "GIS in Education: A Vision for the Future" (Barbara Buttenfield); (5) "Student as Scientist in the Global Laboratory" (Robert Tinker); (6) "GIS State of the Art" (Michael Goodchild); (7) "National Science Education Standards" (Angelo Collins); (8) "National Geography Education Standards" (Sarah Bednarz); (9) "Cognitive Apprenticeship and GIS" (Robert Lima); (10) "Educational Applications of GIS: A Developmental Psychologist's Perspective" (Lynn Liben); (11) "A Convergence of Themes in Educational Reform" (Richard Audet); (12) "NCGIA Secondary Education Project" (Stephen Palladino); (13) "GIS in a Geosciences Curriculum" (Kathryn Keranen); (14) "Urban Environmental Education in Detroit" (Randall Raymond); (15) "National Student Weather Network" (Donald La Salle); (16) "GIS and Environmental Education" (Reinhold Friebertshauser); (17) "Monarch Butterfly Migration Student Investigations" (Steve Case and Brad Williamson); (18) "Exploring Student Problem-Solving Strategies with GIS" (Richard Audet); (19) "ESRI's Educational Initiatives" (Charlie Fitzpatrick); (20) "Kids, Satellites, and Ground Truth" (Barrett Rock); (21) "GeoSphere Project" (Tom Van Sant); (22) "Satellite and Surface-based Observations of Atmospheric Aerosols" (Rudolf Husar); (23) "ESRI Arc View" (Charlie Fitzpatrick); (24) "IDRISI" (John Auble and Michele Fulk); (25) "GEOSCOPE: The Encyclopedia of Planetary Changes" (Luc

Michaud); (26) "GAIA Software" (Suzanne Meyer); (27) "Alice Network Software" (Alan Feldman); (28) "Accu-Weather Forecaster" (Daniel Barstow); (29) "National Geographic Kids Network" (Monica Bradsher); (30) "EOSAT: Remote Sensing and GIS" (Anthony Shupin); and (31) "SimCity 2000" (Daniel Barstow). Editorials from the participants include: (1) "Reflections on the EdGIS Conference" (Charlie Fitzpatrick); (2) "Issues in GIS in Education" (Terry Woronov); (3) "Enhancing Environmental Education" (Duane Nellis); (4) "Defining GIS-A Note of Caution" (Kay Weller); (5) "New Interface Technologies" (Richard Bolt); (6) "Enhance Educational GIS with Hypermedia and Local Databases" (Derek Thompson); (7) "Editorial on Conference Recommendations" (Richard Audet). Resources listed include organizations, GIS and other mapping software, data sources, and conference participants. (JRH)

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First National Conference on the Educational Application of Geographic Information Systems (EdGIS)

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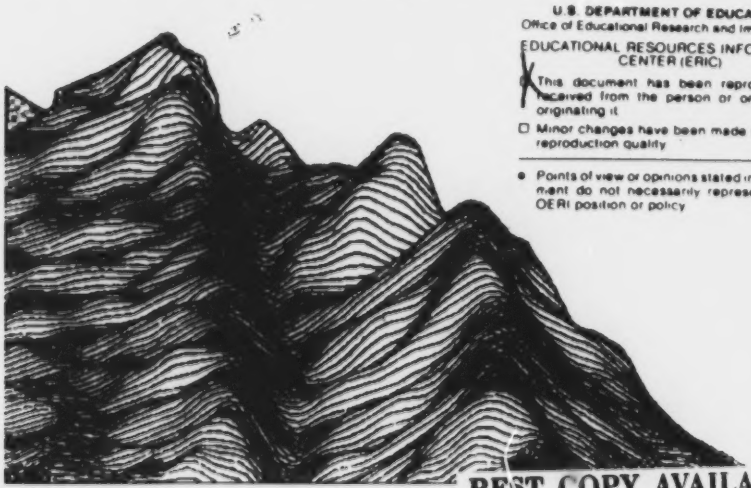

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First National Conference on the Educational Applications of Geographic Information Systems (EdGIS)

Conference Report

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Robert F. Tinker — *Principal Investigator*

Daniel Barstow — *Project Director*

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Executive Summary and Recommendations

Executive Summary

Maps are essential tools of exploration and communication. They exploit the power of visualization to help us interpret and convey large amounts of data. Over the past two decades, computerized electronic maps and the emerging field of Geographic Information Systems (GIS) have dramatically extended this power, by enabling users to create their own maps, perform sophisticated spatial analyses, and visualize the inter-relationships among multiple data sets. GIS is now a multi-billion-dollar-a-year industry, with major applications in geology, biology, meteorology, economics, government, industry and the social sciences. Just as word-processing redefines the creative writing process, interactive GIS redefines the map creation, interpretation, analysis and communication process.

The impact and potential of GIS is now beginning to be felt in education. Decreasing cost of hardware and software, widespread availability of data sets, and improvements in ease-of-use are enabling students and teachers in pioneering projects to explore the use of GIS to support education. Students and teachers have begun to use GIS systems to explore their environment, to better understand key concepts in science, geography and other domains, and to develop skills of problem-solving, data analysis, visualization, and communication. It is precisely the interactive nature of these maps which make them such powerful tools for students, enabling them to actively explore dynamic maps and data, rather than simply looking at maps created by others. GIS has the potential to be a major educational tool, supporting more effective learning of science concepts and providing new tools for inquiry-based learning, as called for in the emerging National Science Education Standards.

Recognizing this potential, the First National Conference on the Educational Applications of Geographic Information Systems (EdGIS) brought together national leaders in education, Geographic Information Systems, and the cognitive sciences to explore the emerging field of applying GIS and other mapping software to pre-college education, and to develop recommendations for further research and development. EdGIS was an invitational conference, with a distinguished group of 60 participants, representing a broad range of organizations. Participants included teachers, research specialists, and representatives of government, education, science, geography, and research organizations. The EdGIS conference was funded by the National Science Foundation, Directorate for Education and Human Resources, Elementary, Secondary, and Informal Education Division, and was coordinated by TERC (a nonprofit educational research and development company). The conference took place in Washington, DC, on January 27-29, 1994.

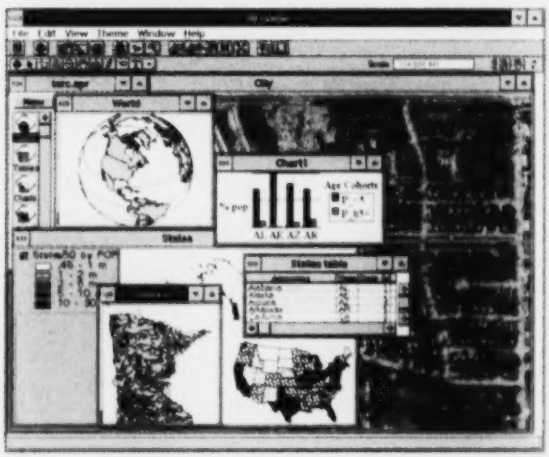
The goals of the conference were to: provide an opportunity for the participants to meet, share experiences, and begin a dialog; showcase current applications of GIS, remote sensing, and other mapping software in pre-college education; develop a better understanding of the current state of the art in both GIS software and related curriculum development; prepare recommendations for further research and development in GIS; and promote public awareness and support for the educational uses of mapping software, through wide distribution of the Conference Report and media coverage of the EdGIS Conference.

GIS encompasses a range of software tools, data sources, and strategies for spatial analysis, enabling the use of computers to display and analyze data interactively on maps. GIS is widely used in government, business, and scientific research. Commercial examples include: government agencies using GIS to create topographical and other analytical maps; cities using GIS to record property boundaries, monitor public services, project housing patterns, define school districts, and allocate resources for public utilities; biologists using GIS for population and migration studies; and geographers using GIS to

maintain maps with the most current available data. A broad view of GIS also includes the use of satellites and remote sensing for studies of the land, oceans, atmosphere, and biosphere.

The revolution in GIS most dramatically impacting education is that GIS software and data are approaching a cost and ease-of-use range that makes them accessible to high schools, middle schools, and even elementary schools. This presents tremendous opportunities for student learning in science, geography, math, history, and in the development of visualization, spatial understanding, problem solving, investigation, and other essential thinking skills.

The conference included presentations by pioneering teachers at the middle and high school levels who are using GIS with their students. In Kathryn Keranen's 12th grade geoscience class (at Jefferson High School for Science and Technology, Fairfax, Virginia), students map and study the local area, as well as environmental events such as the 1988 fires of Yellowstone, the Mississippi flood, and the oil fires of Kuwait. Randy Raymond (Urban Environmental Education Program, Detroit, Michigan) helps urban, disadvantaged students better understand their environment through the use of GIS to map their city and analyze its resources. Brad Williamson and Steve Case (Olathe High School, Olathe, Kansas) team teach a biology class in which students, collaborating with their peers around the country, study Monarch butterfly migration by tagging and monitoring the flight paths of thousands of butterflies. Reinhold Friebertshauser (University School, Hunting Valley, Ohio) and his students study a local lake and its watershed by observations and data collection of geologic, hydrological, atmospheric, and other factors, and then analyze these factors and their interrelationships using GIS.



Sample screen showing multiple GIS displays. Screen image is provided courtesy of Environmental Systems Research Institute, Inc. Copyright © 1994 Environmental Systems Research Institute, Inc.

Conference participants felt that GIS has the potential to make a significant contribution to education. GIS can help support implementation of the national standards in science, math, geography, and other subjects. It can help students understand large amounts of data, better internalize essential content matter, and develop skills of visualization and problem solving. And it can help students prepare for the future, as GIS will become an increasingly useful and prevalent tool in personal, educational, government, and commercial applications.

However, the reality is that we are still in the early stages of the use of GIS in education. As fine as the above-cited teaching examples are, they are rare, and they represent considerable effort and leadership on the part of these individuals. For GIS to have a broader impact on education, progress needs to be made in several key areas of implementation. During the conference, several working groups met to discuss issues, concerns, and recommendations, including educational goals, curriculum needs, software design, data resources, pre- and in-service teacher education, and cognitive research. After the conference, a core group of participants worked further to refine the list of recommendations.

The recommendations include: development of exemplary curriculum materials using GIS; adaptation of existing GIS software for greater ease of use and accessibility to students; review of the vast array of data sets to target those which support educational goals, are appropriately geo-referenced, and are easily imported into GIS packages; development of teacher training resources; and networking among educators, scientists, and GIS professionals in support of these efforts.

These are not insurmountable challenges. On the contrary, this conference demonstrated not only the tremendous potential of GIS in education, but also the number of people eager to support the development and implementation of GIS applications for pre-college education. The EdGIS Conference was, therefore, a crucial opportunity for a group of individuals with expertise in education, GIS, and cognition to explore the current state of the art and to consider ways to help this field move forward. This Conference Report, with its discussion of key issues, classroom examples, recommendations, and resource guide, is a key element in the outreach to build awareness, disseminate these initial ideas, and promote development of educational uses of GIS.

Our hope is that this report and recommendations will have an impact on the leaders in education, GIS, and allied areas who are in a position to promote expanded use of GIS in education. Ultimately the power of GIS will be too compelling to be ignored.

Recommendations

The First National Conference on the Educational Applications of Geographic Information Systems, known as the EdGIS Conference, was held in recognition of the increasing interest in using GIS and other mapping software in an educational context. During the conference, several working groups met to discuss issues, concerns, and recommendations, including educational goals, curriculum needs, software design, data resources, pre-and in-service teacher education, and cognitive research. After the conference, a core group of participants worked further to refine the recommendations presented in this report.

That GIS can make a powerful contribution to education was the consensus among the participants and working groups. There was also a strong feeling that we are at a critical formative stage in which our actions can help define and direct the development of this field. Several key areas and specific tasks were identified where research, development, and implementation support can make a significant difference in how well our nation's students benefit from the power of GIS over the next several years.

These recommendations are directed to a broad set of people and organizations who can assume vital roles in the successful development and use of GIS in education. This intended audience includes:

- Teachers
- Education and curriculum specialists and key organizations
- University faculty and research scientists
- Federal, state, and local government agencies
- GIS software companies
- Data sources
- GIS users
- Foundations and other potential funding sources
- Telecommunications specialists

Many people are already exploring and developing applications of GIS in education, in powerful and creative ways. The conference participants represent some of these efforts, and their work forms the foundation on which these recommendations build.

This report and recommendations, which will be widely distributed, are likely to have an impact not only on the teachers using this as an awareness and resource document, but also on the leaders in education, GIS, and allied areas, who are in a position to promote expanded use of GIS in education.

Clarify Educational Goals

GIS can be used in many school subjects to support a broad range of educational goals. Clarifying these goals is an essential step that forms the foundation for subsequent planning, development, and implementation efforts. On the systemic level, there should be examination of the ways that GIS can support implementation of the national education standards in science, mathematics, geography, and other subjects; statewide curriculum frameworks; and other national, state, and regional curriculum initiatives. On the local level, implementation of these goals is ultimately determined by individual teachers, and therefore GIS awareness initiatives are needed to help teachers consider the value of GIS on an informed basis.

As an initial framework for considering these goals, that GIS can be used to help students:

- Learn content knowledge
- Develop thinking skills, such as visualization, data analysis, and problem solving

- Access and explore geographically based data
- Investigate real-world problems at local, regional, and global levels
- Develop technological literacy in the use of computers, GIS, data sources, and telecommunications
- Become aware of careers in GIS-related fields.

Develop Curriculum Materials

A critical need exists for curriculum materials to help teachers make effective use of GIS with their students. This requires both research on existing efforts and development of new curriculum materials. These materials should have introductory components as well as extension activities. They should cover various subjects and grade levels, including:

- identifying and publicizing existing GIS-based curriculum materials
- preparing an Introductory Guide to GIS for Teachers
- establishing development projects to create exemplary GIS-based curriculum materials in a range of subject areas and grade levels
- developing examples of the use of GIS to enhance existing curricula.

Select and Adapt GIS Software for Education

GIS software is becoming more available to schools because of three major factors: reduced cost simpler interfaces, and lower hardware requirements. While these trends are likely to continue, the reality is that most GIS software was designed for advanced commercial applications rather than for pre-college education. The Resources section of this report includes a list of currently available GIS software recommended for use in education. GIS software should be enhanced for school use by:

- adapting commercial packages for easier use, by creating versions with fewer functions or providing tools for batch commands (or new menu items) to simplify multi-step tasks
- increasing the power and sophistication of educational "mapware" packages, which are already easy to use, in order to add more advanced GIS features
- designing and building educational GIS packages from scratch
- preparing GIS software documentation specifically for students and teachers.

Identify and Provide Access to Data Sources

Ultimately, having a wide range of data sources is the critical element in enabling diverse curricular applications of GIS. The Resources section includes specific data sources that are currently available at low cost to schools, including base maps and scientific and social data. However, with these and other data sources there are difficult and challenging issues of data access, format standards, storage, and appropriateness for education. The recommendations, therefore, relate to both pedagogical issues (what data best support the educational goals) and technical issues (how to overcome technical barriers to access):

- developing an Educational GIS Data Resource Guide, to help teachers identify specific sources of data for their educational goals. It would build on the data sources cited in this report and would be available on-line to support ongoing additions and refinement.
- collaborating with government agencies which produce data, especially the US Geological Survey
- tapping into the increasing power of Internet and telecommunications for access to data
- encouraging data sources to provide educational data products, in standard formats and at low cost
- preparing and distributing CD-ROMs with sample data sets for educational use
- engaging students in projects in which they collect and distribute data
- participating in national efforts to standardize GIS data formats.

Promote Professional Development

Teacher training efforts are essential at both the pre- and in-service levels. The caveat here is that simultaneous progress is needed on resolving some of the issues of goals, curriculum, software, and data. This is not to discourage teacher training, but rather to avoid overselling GIS to a large group of teachers before we are able to providing adequate ways for them to follow up in their classrooms. Specific recommendations are:

- continuing existing teacher training programs to maintain a base of knowledgeable teachers
- developing model training materials
- preparing introductory guides to help teachers get started
- promoting multiple pathways for training, including effective teacher guides, software tutorials, workshops, and on-line support networks
- establishing a World Wide Web server to showcase educational GIS applications.

Support Multiple Levels of Technology Access

Some teachers and students have convenient access to advanced technology, such as computer labs with high-power computers and high-speed data lines, while others have much more limited access. Toward this end, there should not be a single GIS solution for all situations. Specific recommendations are:

- including both high-tech and low-tech options in curriculum materials
- exploring "GIS without computers," such as plastic overlays on paper maps and remote-sensed imagery from books and posters
- supporting school/industry collaborations, such as ESRI's Adopt-a-School program.

Support Inclusion of Underserved Populations in GIS efforts

These efforts should work toward equity of access, especially in relation to minorities, disadvantaged students and other traditionally underserved populations. Ironically, cities tend to have a richer diversity of GIS data sources than other areas, through metropolitan services and government agencies, and thus are potentially "GIS-advantaged." It is also important to consider women as underserved, since women and girls have tended to be less likely to engage with technology than boys. Specific recommendations are:

- ensuring that disadvantaged districts are included in demonstration and development projects
- developing an experience base and guidelines for use of urban GIS data resources
- assuring that in all applications, girls are equitably included and supported.

Conduct Research

GIS in education is a very new field with much to learn. Development and demonstration efforts should include a research component, with widespread dissemination of the research questions, findings, and suggestions for further investigation. Areas of research and sample topics include:

- *Learning and Cognition*—What is the impact of GIS on student learning? Are there subject areas where GIS is more beneficial than other areas? Is there a progression in the development of GIS analytical skills? How do different students respond to the opportunities to use GIS?
- *Curriculum*—What applications are teachers and students most interested in exploring, and what are effective means for developing the appropriate curricula?
- *Software*—In what contexts and domains are specific software packages most useful. How can GIS software be made more effective for education?

- *Data sources*—What domains of exploration most interest students, and how can the requisite data be accessed or created?

Improve Communication and Collaboration for Educational GIS

There is a tremendous need for improved communication and collaboration among people involved with or interested in GIS in education. This includes teachers, GIS specialists, university faculty, individuals, and organizations involved in science, geography, and other educational domains, government agencies, and specialists in cognitive development. Among the vehicles for communication and collaboration, those with highest potential benefit include:

- conferences, like EdGIS, which focus specifically on GIS in education
- electronic communications, such as the EdGIS ListServ
- publications, such as this EdGIS report
- articles in journals of education, GIS, geography, and other domains
- linkages between the education and GIS communities
- an electronic clearinghouse to support dissemination and communication.

Grand Challenge

In emerging fields such as GIS in education, a "grand challenge" can serve as a driving force and can provide the context for benchmarks to measure progress. The Geosciences provide a context in which our goals in education and our hopes for the educational applications of GIS can come together in such a grand challenge—for students, in collaboration with teachers, GIS specialists, and scientists, to develop a deeper understanding of the Earth's problems and create solutions that can help improve the quality of life on our planet and its chances for long-term survival. Such a vision provides a rich and rewarding context for exploring, exploiting, and evaluating the power of GIS in education.

Introduction

Overview of the Conference

The First National Conference on the Educational Applications of Geographic Information Systems, known as the EdGIS Conference, brought together national leaders in education, Geographic Information Systems (GIS), and the cognitive sciences in order to explore the emerging use of GIS and other mapping software in education and to develop recommendations for further research and development. Funded by the National Science Foundation, the EdGIS Conference was coordinated by TERC and took place in Washington, DC, on January 27-29, 1994. Sessions were held at the National Geographic Society and at the Sumner School Museum.

EdGIS was an invitational conference, with a distinguished group of 60 participants, representing a broad range of organizations. Participants included teachers, research specialists, and representatives of government, education, science, geography, and research organizations.

Goals

The goals of the conference were to:

1. Provide an opportunity for the participants to meet, share experiences, and begin a dialog
2. Showcase current applications of GIS, remote sensing, and other mapping software in pre-college education
3. Develop a better understanding of the current state of the art in both GIS software and related curriculum development
4. Prepare recommendations for further research and development in GIS
5. Summarize the conference presentations and recommendations in a Conference Report
6. Promote public awareness and support for the educational uses of mapping software, through wide distribution of the Conference Report and media coverage of the EdGIS conference.

Agenda Overview

The Conference had a very full agenda, especially because so many of the participants were involved in exciting, cutting-edge development and applications. The agenda provided a blend of:

large group presentations—for keynotes and core concepts

break-out sessions—for demonstrations

work groups—to discuss key concepts and to develop recommendations.

While the conference was structured to provide a wealth of scheduled presentations, participants were encouraged to take time to chat informally. An exhibit hall offered displays and poster sessions by participants and industry representatives.

Wednesday, January 26, 1994

Reception—This provided an initial informal opportunity for the participants to meet and talk.

Thursday, January 27, 1994

Recognizing that the participants came from a variety of backgrounds, the goal of the first day was to provide a common foundation, with presentations about major themes and demonstrations of current applications of GIS in education.

Welcomes—Welcome comments were made by Daniel Barstow of TERC, which coordinated the Conference; George Peterson of the National Geographic Society, which hosted the opening session; and Margaret Cozzens and Gerhard Salinger of the National Science Foundation, which funded the Conference.

Introductory Keynotes—In the opening keynotes, Robert Tinker (TERC) and Barbara Buttenfield (NCGIA, USGS) expressed their visions of the future of GIS in education. Tinker spoke primarily from the perspective of an educator and Buttenfield spoke from the perspective of a specialist in GIS.

For the rest of the morning, the Conference took the educators' perspective, in terms of educational goals, as well as examples of teachers who are at the cutting edge of GIS in schools.

Education Goals—National Standards—Angelo Collins (National Science Standards Project) and Sarah Bednarz (National Geography Standards Project) highlighted aspects of the national science and geography standards, which provide a compelling context and focus for GIS in education.

Educators Taking the Initiative—Five break-out sessions were presented by teachers who are exploring and developing educational applications of GIS. Offering illustrations of the power and breadth of GIS were these sessions:

GIS in a High School Geosciences Course—Kathryn Keranen

Monarch Butterfly Migration—Steve Case and Brad Williamson

Urban Environmental Education in Detroit Program—Randy Raymond

National Student Weather Network—Donald La Salle

GIS and Environmental Education—Reinhold Friebertshauser

In the afternoon the Conference focused on the technology of GIS, demonstrating state-of-the-art GIS and remote sensing, in research and in education:

GIS State of the art—Michael Goodchild presented his views on the state of the art in GIS, as it relates to education. Director of the National Center for Geographic Information and Analysis, he presented several important current issues in GIS, as well as his perspective on the power of GIS for pre-college education.

Presentation by Angelo Collins, Director, National Science Education Standards Project.

Satellites and Remote-Sensing—Anthony Shupin presented an overview of Landsat, along with EOSAT's role in distribution of Landsat images. He also highlighted several educational applications of satellites and remote sensing.

Demonstrations of GIS software—The software demos included several packages currently used in pre-college education:

ESRI ArcView—Charlie Fitzpatrick

IDRISI—John Auble

GeoScope—Luc Michaud

Voyager—Rudolf Husar

MapInfo—Kevin Mahoney

GIS Professionals Taking the Initiative—Five break-out sessions were presented by GIS professionals who are spearheading collaborations with public schools. These sessions were:

USGS Multi-Media Education Project — Barbara Buttenfield

NCGIA Secondary Education Program — Stephen Palladino

ESRI Educational Initiatives—Charlie Fitzpatrick

Satellites and Ground Truth—Barry Rock

GAIA Project—Richard Podolsky

Power of Visualization—The evening keynote was by Stephen Hall, the author of *Mapping the Next Millennium*. He showed how mapping and other tools of visualization are at the cutting edge of research, not only in geography, but also in astronomy, biology, chemistry, and mathematics.

Friday, January 28, 1994

The first part of the morning focused on the cognitive sciences:

Mapping and Thinking—Cognitive Sciences Panel—Richard Audet, Lynn Liben, and Robert Lima shared their innovative research and models for understanding how mapping is a natural and critically important thinking skill that promotes cognitive development. This was a topic of significant interest, and there were other informal discussion groups dealing with the insights the cognitive sciences provide on how to effectively use GIS with students.

Over the next two days there were three Work Groups sessions. During each session the conference split into four sets of work groups, each with approximately 15 people. The goal was to discuss and develop key points on the respective topics.

Work Groups Part I—Scenarios of the Future—A pre-conference planning group defined five scenarios of the use of GIS in education over the next five years. Each work group selected one of the scenarios and clarified the educational goals, added details on the scenario, and considered the technological and educational development required to implement the scenario.

Tour of NGS Cartographic Division—As part of an extended lunch break, the National Geographic Society offered a tour of its Cartographic Division, including its use of GIS software.

The afternoon focused on Resources and Software Innovations:

Resources—This session focused on additional resources for educators interested in exploiting the power of GIS in education:

NCGIA—Stephen Palladino

USGS—William Miller

NOAA—John Schmidt

LTER—John Vande Castle

Internet—Beverly Hunter

Software Innovations—These software demonstrations focused on some innovative approaches to mapping software. While not formal GIS, these tools offer considerable power for education:

Alice Network Software—Alan Feldman

Accu-Weather Forecaster—Daniel Barstow

Geographic Modeling—Mark Sutton

National Geographic Kids Network—Monica Bradsher

SimCity 2000—Harold McWilliams

GeoSphere Project—For the evening keynote, Tom Van Sant presented the GeoSphere Project, of which he is President, and his vision for students and scientists using geographic visualization as a powerful tool for investigation and collaboration.

Saturday, January 29

The third and final day of the Conference was devoted to assessing the conference and discussing initial recommendations.

Work Groups Part II—Research and Development Priorities—Each of four sub-groups developed initial recommendations for research and development in both technology and education, in order to promote expanded and effective use of GIS and other mapping software in education. This included consideration of both barriers and emerging opportunities.

Wrap-up and Closing Remarks—Michael Goodchild (NCGIA) provided summative reactions to the conference and its recommendations, and the Conference was concluded.

Overview of the Conference Report

This report of the First National Conference on the Educational Applications of Geographic Information Systems (EdGIS) includes the presentations as well as supplemental support material. Where appropriate, we have asked the presenters to update information, which is now current as of November 1994.

The report is divided into six sections. Executive Summary and Recommendations—Executive Summary of the conference and the Recommendations

Introduction — Overview of the conference and an introduction to GIS and its role in education

Setting the Stage — Presentations on overarching themes and issues in the educational uses of GIS

Cutting Edge — Presentations on some current initiatives in which GIS and other mapping software are used in education

GIS Software for Education — Descriptions of GIS and other mapping software packages

Editorials — Commentary by participants on various aspects of GIS in education

Resources — A guide to resource organizations, software, and data sources for GIS in education, and a listing of the conference participants.

This Conference Report is published by the National Science Foundation and will be widely distributed by national organizations involved with GIS and with science, math, geography, and technology-enhanced education, including the Council of State Science Supervisors, National Center for Geographic Information and Analysis, National Council for Geographic Education, National Geography Alliance, National School Boards Assocation, National Science Supervisors Association, National Science Teachers Association, TERC, and other advocates for GIS in education.

An Introduction to GIS in Education

by Daniel Barstow

Daniel Barstow, of TERC, was the Project Director for the EdGIS Conference and Editor of the Conference Report. He is also Project Director for the NSF-funded Kids Network curriculum project. Previously he was a teacher and Coordinator of Gifted and Talented Programs in the Hartford Public Schools, Assistant Director of the Talcott Mountain Science Center, and President of Metacomet Software, as well as author of the Accu-Weather Forecaster software package. His current focus is on helping teachers and students do real-world investigations using GIS and remote sensing, especially in urban schools.

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Maps represent one of the fundamental tools by which we make sense of the world around us. — Stephen Hall

When we think about the use of Geographic Information Systems in education, we need to think about both GIS and education. We need to think about the power of GIS for visualization and spatial analysis, the vast diversity of data, and the new ways of exploration and thinking that it enables. And we need to think about what we want our students to learn, and how we believe that learning can take place most effectively .

What is GIS?

The question really should be what *are* GIS, because GIS encompasses a broad range of software tools, data sources, and strategies for spatial analysis. GIS is in fact a multi-billion dollar a year industry, with over 250,000 people worldwide doing some form of work with GIS. Current applications of GIS include:

Map development — The US Geological Survey uses GIS to maintain, update, and produce a tremendous variety of maps, incorporating current topographical geological, biological, oceanographic, and other data.

Town planning — Many cities and towns use GIS to record property boundaries, monitor public services, project housing patterns, define school districts, and allocate resources for public utilities.

Environmental protection — Biologists concerned about endangered species use GIS software and a process called "gap analysis" to analyze migration patterns, terrain, vegetation patterns, and property values that identify critical pieces of property for acquisition to fill in gaps in the migration paths.

Atmospheric research — Atmospheric scientists use GIS to record, display, and analyze a variety of atmospheric data, such as fluctuations in stratospheric ozone levels.

Political campaigns — Candidates for public office, especially at the national level, use GIS to monitor the geographic distribution of bases of political support and determine where to focus campaign resources.

World resources — The United Nations, the World Resources Institute, and other worldwide planners use GIS to better understand the distribution of resources, status of economic indicators, educational levels, health issues, and other measures of needs and resources throughout the countries of the world

The revolution in GIS most dramatically impacting education is that GIS software and data are now approaching a cost and ease-of-use range that makes them accessible to high schools, middle schools, and even elementary schools. This presents tremendous opportunities for student learning in science, geography, math, history, and in the development of visualization, spatial understanding, problem solving, and other essential thinking skills.

To introduce GIS, I would like to provide a conceptual basis by building a hypothetical GIS package, from the simplest to more advanced features.

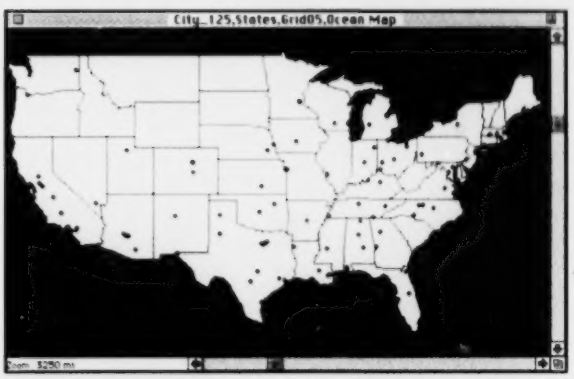


Figure 1. Base map with state boundaries using MapInfo Software.

Map-on-a-computer — Our GIS package begins with the ability to draw maps on a computer (Figure 1). Two key elements define this feature: a database of map information, such as the coordinates which define the boundaries of countries, states, or towns; and the software's ability to use this information to draw maps.

Manipulating the map — Next we add the ability to manipulate the map, such as zooming in for a closer look or panning to nearby areas. Our GIS package adds more details as we zoom in and, for example, as we zoom from a national view into a local view, we start to see the shapes of cities and towns, instead of just points to indicate their locations.

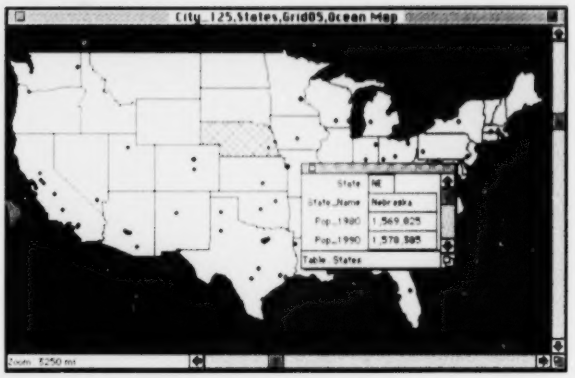


Figure 2. Database for a selected state (Nebraska) using MapInfo Software.

Database with attributes — Every object displayed on the map is defined in a linked database,which describes where and how to draw the object, and includes related reference information (Figure 2). For example, a GIS database for the US might have fields of data for each state indicating the shape and location of its boundaries, as well as reference data about the state, such as total population, ethnicity, education levels, and economic conditions. Called a geo-referenced database, the linking of the attributes with the geographic location is a key element of the GIS. One of the simplest forms of query that we can pose to the GIS is to mouse-click on a point in the map display and have the GIS display the data associated with that point.

Visualizing the data — We now add several ways to represent the data visually, including coloring, shading, symbols, bar graphs, and contouring (Figure 3). Shading, for example, enables you to visualize patterns that are not easily seen by looking at raw data. Your choice of display technique depends on the nature of the data, the type of analysis that you are interested in, and the needs of the intended audience. Selecting among these display options is one of the skills of GIS use.

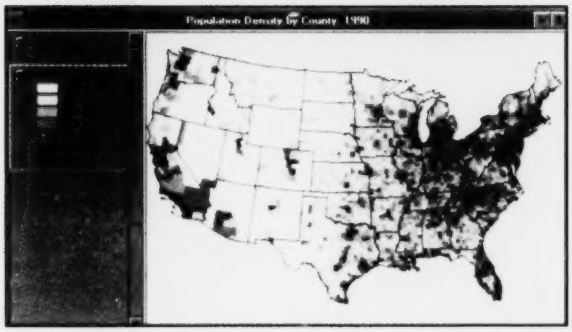


Figure 3. Map showing population density. Screen image is provided courtesy of Environmental Systems Research Institute, Inc. Copyright © 1994 Environmental Systems Research Institute, Inc. All rights reserved.

Layers — The next addition to our GIS is the ability to display simultaneously several types of data, which we can envision as several layers of data (Figure 4). This enables you to see the inter-relationships among different types of data for the same locations. For example, in a map of a city, we might have an aerial photo as the base map, then add layers to show property boundaries, water and sewage systems, and the location of public services. Our GIS enables us to select which layers to display, the sequence in which they are drawn, and the colors or patterns used to represent each layer.

Figure 4. Checkmarks on the left side of the screen select layers of data to display. Screen image is provided courtesy of Environmental Systems Research Institute, Inc. Copyright © 1994 Environmental Systems Research Institute, Inc. All rights reserved.

Computer-based Spatial Analysis — At the most advanced level, GIS packages can do automated queries and spatial analysis. For example, a real estate agent can have the GIS show all homes for sale in a given price range, within walking distance of a school. Or an environmentalist can query for all potential sources of pollution in the watersheds of the lakes and rivers in a given region. The nature of such capabilities varies from one application to another, based in part on what data are available and how they are organized, and in part on the software features of the package.

Toward a Broadened Concept of GIS

The above description relates to one type of GIS, commonly called vector GIS, in which all map objects are defined as vectors, such as points, lines, and polygons (see "ESRI ArcView").

Another major type of GIS is raster, or grid-based, GIS, which divides the mapped area into squares of a grid, much like a graph paper. Each square can be displayed as a particular color, or colors, based on the values associated with it. Without going into the details here, raster GIS can be used for some very powerful types of spatial analysis. In general, natural phenomena are best represented using grid-based GIS, whereas objects constructed by humans are best represented using vector GIS (see "IDRISI").

Other types of computerized mapping tools and databases, though not the prime focus of this conference, were included to demonstrate the depth and breadth of computer-based maps. In this sense, the EdGIS Conference attempted to use a broadened concept of GIS that encompasses not only the formal GIS tools, but also other forms of map-based software such as the following examples.

The use of Earth-orbiting satellites and the remote-sensed images that they provide is a very broad and powerful domain of GIS (Figure 5). A tremendous amount of spatial analysis can be done with satellite images, with the multi-spectral information and detailed imagery (see "EOSAT," "GAIA Software," and "GeoScope").

Figure 5. Satellite View of Earth using Accu-Weather Forecaster.

Among mass-market software are several easy-to-use educational mapping packages for computer-based display and analysis of world and national data. For example, Broderbund's *Maps and Facts* enables students to explore a wide range of data on computer-based maps, including social, economic, educational, and other important information. Another example is National Geographic Kids Network, a series of curriculum units in which students collect local environmental data and share their data with other students using telecommunications. NGS Kids Network includes software for map-based display and analysis of the data. Though the map displays of such packages have considerable flexibility and can be very educational, they are not considered "true GIS" since they have limited capabilities for spatial analysis.

Two map-based computer games were included in the conference as an effort to stretch the imagination. Maxis Software's *SimCity* is a fantasy game in which one designs and builds an imaginary city. The development of each city is based on a remarkably sophisticated interaction of geographic information. Microsoft's *Flight Simulator* enables one to fly over and explore selected cities of the world, using satellite images as the base map for the exploration. While neither of these tools is a GIS, they offer educational power, engage students, and challenge us to think creatively about the future of GIS in education.

Educational Applications of GIS

Selecting, designing, developing, and implementing educational applications of GIS must begin with defining our educational goals. This is not, of course, a simple task. Several national organizations have been working for several years to develop national educational standards in science, math, geography, and other domains. State level efforts include the NSF-funded State Systemic Initiatives and Curriculum Frameworks, which are linked with state-mandated educational goals and objectives. Every local district is required to define its own goals and priorities within these state and national contexts. And ultimately, educational goals are implemented by the individual teachers, for whom teaching is a never-ending set of judgments and decisions on how best to help their students learn.

Rather than survey these diverse efforts at defining goals, I would like to suggest a simple framework for thinking about the use of GIS in education, which I believe is in concert with the general themes and directions of the emerging national standards and the current wave of educational reform.

1. *Students should learn content*—Our purpose here is not to pre-determine the optimal content, but rather to reinforce the concept that science, math, geography or other content areas are at the heart of our uses of GIS in education. A biology class might focus on a study of migration corridors; a geology class might use remote-sensed images to study volcanic activity; a history class might study migration patterns; an urban studies class might use GIS to better understand local planning issues. Each domain has a core set of facts and skills for students to learn, experience, and understand, and has other areas into which the exploration can extend based on student interests.

2. *Students should develop thinking skills*—GIS is, first and foremost, an analysis and problem-solving tool. GIS can help students develop skills of visualization, data analysis and representation, problem solving, evaluation and communication.

One of the challenges in learning to use GIS is to make the paradigm shift which allows you to ask different kinds of spatial questions — a shift, for example, from "Where is X?" to "Why is X here?"

3. *Students should explore real-world problems*— A prevailing theme throughout this conference was the central importance of engaging students in hands-on investigations of real-world problems. For example, we find that students are more excited about meteorology when they are examining live weather data than when they are simply reading about weather in textbooks. Virtually every presenter emphasized this type of hands-on investigation approach. GIS is almost by definition a real-world investigation tool.

4. *Students should learn skills of collaboration*— Increasingly science is becoming a process of collaborative investigation. Both within the lab (or classroom) and across telecommunications networks, students should learn skills of collaboration, working in teams as they explore the data, carry out their investigation, and share their findings with others. Collaboration is a key element in projects such as Kids Network, Global Lab, and GLOBE. Data sharing becomes critical to success in many types of investigations.

5. *Students should prepare for careers in GIS*—Since GIS is a multi-billion dollar industry, and growing at a rate of 20-30% per year, career development in GIS can have some very real benefits for students. In this sense, GIS itself becomes the topic of study, with students learning more about GIS tools and how they are used in government, business, and industry. Whether they pursue "GIS-focused" careers or use GIS as a support tool for their future studies and jobs, students gain by an understanding of, and ability to use, GIS. Many believe that GIS will become nearly as prevalent in jobs as word-processing, databases, and spreadsheets, especially given the vast amount of data becoming available through Internet and other computer networks.

By way of example. . .

To illustrate the educational applications, I would like to cite several examples of the innovative teachers and other educators who shared their work at this conference. In doing so, we must recognize that these individuals are the pioneers who are paving the way for the settlers to come. (See the section *The Cutting Edge: Some Current Initiatives.*)

Kathryn Keranen (Jefferson High School for Science and Technology, Fairfax, Virginia) teaches a 12th grade geoscience class in which students use GIS to construct a digital elevation model of a hill on the high school campus, including contours of the hill and vegetation polygons. The class then proceeds with an extensive unit on remote sensing data and its use in solving problems, including Landsat images of the fires of Yellowstone and the Mississippi flood. Once students are well-grounded in GIS, they undertake individual investigations in a variety of areas.

Randy Raymond (Urban Environmental Education in Detroit Program) uses GIS to help urban, disadvantaged students better understand their city environment. Using GIS to map their city and analyze its resources, the students serve as GIS resource specialists to numerous urban organizations. Randy reports that this program increases his students' sense of connection to Detroit beyond their local neighborhood and deepens their understanding of the complex nature of urban environmental problem solving.

Brad Williamson and Steve Case (Olathe High School, Olathe, Kansas) team teach a biology class that emphasizes student investigation of real-world problems. One area of student interest is migration of the Monarch butterfly, an investigation conducted collaboratively with other students throughout North America. Every year these students tag thousands of butterflies, with tags color-coded to region. Areas of research include analysis of migration pathways, impact of weather on migration, and comparison of fall and spring migrations. All these analyses take advantage of GIS for visualization and spatial analysis and also combine biology, math, and other content areas.

Reinhold Friebertshauser (University School, Hunting Valley, Ohio) uses the 200-acre campus and 5-acre lake as a unique outdoor classroom. The first component of the course involves a survey of various types of scientific data and methods of analysis including geology, geography, ecology, and meteorology. The second component applies this background to the local environment by creating a GIS of the local watershed. Data are collected on topography, water and soil temperature, water quality, vegetation cover, land use, and other environmental measures. Once these features are incorporated into the GIS database, students can begin to look at relationships previously too cumbersome to analyze.

Richard Audet (Boston University) observed teachers and students in several Wisconsin schools as they learned how to use GIS and characterized their different approaches to problem solving. He found a development of problem-solving skills that grew with increasing experience with GIS. Novices were more likely to use trial and error strategies, act before shaping a full strategy, and rely on their own visual interpretations of information. GIS experts, in contrast, tended to conceptualize a problem in terms of its essential, or "deep structure" characteristics, make effective use of computer-based queries, and develop effective representations for communicating their information.

Issues of Implementation

GIS has the potential to make a significant contribution to education. It can support implementation of the national standards in science, math, geography, and other domains. It can help students make meaning of large amounts of data, internalize essential content matter, and develop skills of visualization and problem solving. And it can help them prepare for the future, as GIS becomes an increasingly useful and prevalent tool in personal, educational, government, and commercial applications.

However, the reality is that we are still in the early stages of the use of GIS in education. As fine as the above-cited teaching examples are, they are rare, and they represent considerable effort and leadership on the part of these individuals. For GIS to have a broader impact on education, progress needs to be made in several key areas of implementation: development of exemplary curriculum materials, increased access to and standardization of data, teacher training, and dealing with issues of equity of access. This will require leadership, collaboration among the education and GIS communities, development and dissemination efforts, and networking among developers and practitioners.

Nonetheless, these are not insurmountable barriers. On the contrary, this conference has demonstrated not only the tremendous potential of GIS in education, but also the number of people eager to support its development and implementation in pre-college education. The EdGIS Conference has, therefore, been a crucial opportunity for a group of individuals with expertise in education, GIS, and cognition to explore the current state of the art and to consider ways to help this field move forward. This conference report is a key element in the outreach to the wider education and GIS communities to build awareness, disseminate these initial ideas, and promote development of educational uses of GIS. Ultimately, the power of GIS will be too compelling to ignore.

Reference

Hall, S. (1992) Mapping the Next Millenium. New York: Random House.

Potential Scenarios for GIS in Education

In order to provide a context for the action recommendations, conference participants prepared a set of scenarios of the future. These scenarios represent educational applications of Geographic Information Systems that take advantage of its emerging power and meet the general educational goals of active student investigation of real-world problems and development of visualization and data analysis skills.

This is by no means an all-inclusive list; it is an attempt to provide substance to our visions. Furthermore, the diversity of the scenarios reflects the wide range of interests of the participants and their students. Several of these scenarios build on current work, including projects represented at this conference.

After developing the scenarios, the participants reflected on the student learning goals that might be achieved through each scenario; technological requirements in terms of hardware, GIS software and data; curriculum support materials required; and teacher training needed. The recommendations in this report are based, in part, on these implementation requirements.

Our Town

In this scenario, students use every available resource to study the geography, history, and environment of their town or city. Using GIS and a good base map, the students create an evolving GIS database of information about their community, including natural resources, residential history, population, commerce and industry, and available services and areas served. They use this database and a multimedia guide to Our Town both for their own investigations and as a resource for other students and community residents. With their evolving database and GIS expertise, the students also become a resource for community organizations seeking to improve local planning and services. The system is an ongoing process, with students from various schools contributing additional information to the comprehensive integrated database over a several year period.

Students and Scientists Working Together

In his book *Earth in the Balance*, Vice-President Al Gore proposed a network of students collaborating with scientists to investigate real-world problems—conducting measurements on a range of environmental factors and sharing the data electronically. In this scenario, the network is in place, the students are doing the observations, and GIS is being used by both students and scientists to analyze the data. Research and learning are collaboratively developed by scientists, teachers, and students, in order to ensure that the projects encompass real science and effective learning. Curriculum materials are in place to help students learn key concepts of scientific research as well as content relating to the specific domains of the data collection.

Mission to Planet Earth

In 1998, NASA will begin launching a series of new satellites for elaborate, detailed, and sophisticated remote-sensing and Earth resource monitoring. Going beyond the existing set of Landsat, GOES and other satellites, they will provide vast quantities of images and data relating to a broad range of geological, biological, atmospheric, and other environmental measurements. Estimates are that a terabyte of data will be transmitted to Earth every eight days. GIS thus becomes an essential tool for analyzing and visualizing the data. In this scenario, students have direct and immediate access to the same data as the

scientists and begin conducting their own investigations of the data. On one level, the students use these images and data to learn basic concepts of geology, meteorology, and other Earth sciences. On a more advanced level, students participate directly in their own primary research, investigating topics of local, regional, and planetary importance.

GIS in Cultural Geography

In this scenario, GIS-generated maps are at the center of an interdisciplinary study of other regions of the world with a focus on social and cultural issues rather than science. Using data from such organizations as the United Nations and the World Resources Institute, thematic maps are generated and used to study issues of land use, fertility, population statistics, migration patterns, economic development, language and dialect, and political models. Students learn how other cultures interact with the landscape, inter-weaving themes such as ecology, mythology, religion, and architecture. With historical data, this scenario also involves studying changes over time, supporting student investigations in history and social studies classes.

GIS and the Information Superhighway

Internet and other components of the Information Superhighway are providing access to an incredible quantity and diversity of data—many of which are geographically based. These include scientific and social data, as well as a wealth of digitized map data, such as those available through the US Geological Survey. In this scenario, format standards for geo-referenced data have been established, and several GIS/Internet tools have been developed to help students use a map-based interface to search for, access, and display data from multiple network sources. Using these tools to "surf the Internet," students explore a variety of data and investigate relationships among the data. According to some GIS specialists, such visualization tools will become the primary means for accessing networked data sources, not just for students, but also for scientists and the general public.

Apprentice to the Masters

Current estimates are that GIS packages are used professionally in 250,000 locations, with an annual growth rate of 20-30%. In other words, this is an important growth area for jobs. This scenario focuses on career development with students serving as apprentices to GIS professionals in research, industry and government. The apprenticeship is preceded by basic GIS experience so that students are doing real GIS, rather than rote data entry.

Local Wetlands Study

In this scenario, a group of schools throughout the US selects local wetlands for intensive study. For each wetland, the local school does on-site investigative work to develop an accurate base map and then conducts ongoing observations and measurements that are used to create a GIS database linked to the base map. The schools proceed with analysis of the inter-relationships among such features as plant and animal types, water depths, temperature variations, pH values, and other biotic and abiotic factors, as well as the impact of humans on the wetlands. These GIS-based maps and data are shared among the participating students and with regional and national wetlands agencies. Students are actively involved with local studies which are then linked to regional and larger views.

Investigation of an Endangered Species

Bald eagles migrate from lower Canada, where they are hatched, to the southern United States, generally following rivers and streams and fishing in the shallow waters. The clutch size of bald eagles is sufficient to ensure maintenance of the population size, if not an increase, yet the size of the population continues to decrease. There is no evidence of chemical pollution that may affect reproductive viability in the nesting sites. In this scenario, students explore the factors that might be influencing the reduction of the eagle population. The students generate possible hypotheses, propose appropriate questions, identify the data necessary to investigate these hypotheses, and determine the means by which they will collect those data. The students proceed

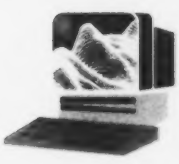
with the research, in collaboration with scientists. This scenario provides a hands-on opportunity to work with a real issue that engages students in problem solving, as well as helping them learn about habitats, migrations, biotic and abiotic factors in the environment, and the impact of humans on other organisms.

Interplanetary GIS

Voyager, Viking, Magellan, and other inter-planetary explorations produced marvelous images and a wealth of data about all the planets in our solar system except Pluto. Coupled with other recent and anticipated probes, these data and images provide fertile territory for students to explore along with scientists. In this scenario, students take a "grand tour" of the solar system, stopping at each planet to do GIS-supported investigations. It is not unreasonable to think that students might even make some discoveries that the scientists themselves have not yet found. In the context of such inter-planetary comparisons, they also learn more about our own planet Earth.

. . .And Even Art

At their best, maps are beautiful works of art. Whether one is looking at photos of Earth taken by space shuttle astronauts, colorful thematic maps, or some of the latest imagery from the most powerful GIS systems, maps can be appreciated for their sheer beauty, as well as for the knowledge they represent. In this scenario, students in an art class are turned loose with a GIS package to create maps with a sole focus on the beauty of the images created. They have a free hand to be as realistic or imaginative as possible.



Setting the Stage

Themes and Issues in the Educational Uses of GIS

The Charge from the National Science Foundation

by Gerhard L. Salinger

Dr. Gerhard L. Salinger is a Program Officer in the Division of Elementary, Secondary and Informal Education at the National Science Foundation, where he is responsible for funding the development of instructional materials at the secondary level and the Advanced Technological Education Program for two-year colleges. A physicist with a PhD from the University of Illinois/Urbana in low temperature physics, he was on the faculty at Rensselaer Polytechnic Institute, Troy, New York, for 25 years. One interest is in ways to prepare a broader cross section of students for careers in technological fields.

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Welcome to this conference, which was in fact brought about by you—the participants. The Instructional Materials Development Program in the Division of Elementary, Secondary and Informal Education at the National Science Foundation began receiving proposals to apply Geographic Information Systems to education. The panelists reviewing these proposals liked them. The program officers reviewed the proposals, and we liked them. But there were always many issues that could not quite be resolved. Several meetings were held with program officers from different divisions in the Education and Human Resources Directorate and also with the geographers at NSF. The discussion turned to getting "ahead of the curve" and to ways of influencing the content of proposals. Fortunately, at about the same time, TERC offered to organize a conference on GIS. This conference is the result, and we are looking forward to it.

We are very gratified by the interest in the topic by both the teaching and the research communities. You who are here are the tip of the iceberg. Dan Barstow may be one of the more unpopular people in the country with all of the people who wanted to come and to whom he had to say no.

Last night at the reception, I was asked whether the group was split between those who have come to learn and those who are teaching. I quickly responded, "No, that's not the way it is at all." Everybody in this room has something to teach to someone else at some time, and something to learn at other times. The geography researchers have a lot of information about the content; the teachers have a lot of information about how to get it across in the classroom.

This conference starts on an auspicious date. I learned this morning on the radio from Garrison Keillor that today is the anniversary of Mozart's birthday. A nice comparison can be made between music and research. Science research can be compared to a sonata or perhaps chamber music. Engineering research, where you also have to consider economic and other consequences, has the complexity of a symphony. But development of instructional materials, in its complexity, really compares at least

to opera. It is not only the size of the cast needed and the diverse types of people—the people who play the instruments, the people who sing, the people who do lighting, design the costumes, the staging, and so forth. All of this is also very important in instructional materials. I have not even commented on the complexity of the plots in opera. I have heard the garden scene in the last act of the Marriage of Figaro compared to the income tax form; it is extremely complex. In the development of GIS for the classroom, we have similar complexities that have to be sorted out.

We need to have recommendations of where GIS is now, and where it is going to go as a research tool. What are the interesting applications that are being tried now in education? Also, what is the vision? On the technical side, will there be robust Geographic Information Systems in schools that are friendly enough to be used by the students, transparent enough, yet not too transparent? I think one of the fundamental questions is always going to be: What is the learning that produces understanding of concepts and processes students should know and be able to apply? That is foremost. We really do not wish students, at this age at least, to become GIS jockeys.

So the question again is: What insights does GIS allow that the other ways of learning do not? We do not want to see proposals that just, if you want, "jazz up" standard geography or ecology units. What is GIS going to allow in education that we cannot do in other ways?

At the Foundation, we have been learning about educational technologies. We are circulating an internal document which looks at ways that educational technology can offer learning at any time, anywhere, with anybody, and throughout the learner's lifetime. Learning takes place through experiment and discovery. The research that students do should be authentic—working with existing databases, collecting real data, using research standards and protocols.

GIS can offer to students and teachers a number of skills not directly in the content. A few years ago, the Department of Labor produced the SCANS report—The Secretary's Commission on Achieving Necessary Skills. It includes the usual foundation of the basic skills—the 3Rs— thinking skills, and personal qualities. In addition, the report describes five workplace competencies, which GIS can help to teach students. These workplace competencies are not skills needed in the workplace only; they are skills everyone needs at all levels. They include the ability to use productively a) resources—to allocate time, space, money, material, and staff; b) interpersonal skills—to know how to work on teams, teach each other, serve customers, lead, negotiate, work well with people of other backgrounds; c) information—to acquire, evaluate and interpret data, organize and maintain files, interpret and communicate, and use computers to process information; d) systems—social, organizational, and technological—to be able to monitor and correct performance, and design and improve systems; and e) technology—to select equipment and tools, apply technology to specific tasks, and maintain and troubleshoot equipment. It is clear that GIS can also contribute to the education of students for the workplace. GIS must be for ALL students.

I am certain that you will be able to add recommendations for these and other issues. The content of the disciplines of geography, ecology, earth science, etc., is an issue. Recommendations to schools are another. I think one needs to deal with the realities—we want access for all students. Platforms in schools are limited in size. The cost of hardware and software will be an issue, as will maintenance. We have to consider the role of colleges which educate teachers—those providing preservice education and also those providing inservice education.

You can see that there is a whole array of issues that make producing opera look easy. In the end, we want students who have had experiences that can lead to productive lives, both professionally and personally.

I look forward to the results of this conference. However, I sound one other note of caution: Garrison Keillor also pointed out that today is the birthday of Charles Lutwidge Dodgson as well. He is otherwise known as Lewis Carroll.

Welcome from the National Geographic Society

by George A. Peterson

George A. Peterson is the Vice President and Director of the Educational Media Division at the National Geographic Society, where he has worked for 24 years. His responsibilities include financial management, product development, and marketing activities of the Division, whose product lines range from traditional print and audio-visual media to advanced technologies. Flagship programs are National Geographic Kids Network, GTV, and CD-ROM.

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Good morning and welcome to the National Geographic Society. This auditorium [Grosvenor Auditorium] is a very special place. It is named for the Society's first full-time editor who, not so incidentally, given the goals of this group, was a pre-college teacher before he became an editor. Last night Richard Leakey was honored in this room as the recipient of the Society's Hubbard Medal, an award for "distinction in exploration, discovery, and research" named in honor of the Society's first President, Gardiner Greene Hubbard. This room is reserved for Society functions and is not used very often. For this group to be meeting here today is a sign of how much importance the Society places in the work you are undertaking.

My thanks to Bob Tinker and Dan Barstow for giving me the opportunity to welcome you and to talk about the Society's commitment to education.

I have been with the Society for 24 years. In the early years when strangers would ask me, "And, what do you do?" I would say, "I produce educational materials for children." We would talk for a few minutes about filmstrips, and the conversation would drift to sports, real estate, or politics.

In recent years I start by mentioning computer software and telecommunications programs, Kids Network for example, and the conversations get animated. Even here in Washington lawyers seem less likely to look over my shoulder, scanning the room for compatriots.

Conversation these days focuses on fundamental change in education and roles technology can play in improving the lives of teachers and students. We talk about getting the best possible learning tools into the hands of students. We talk about learning styles.

I am a visual learner. That is one reason why I enjoy working for the National Geographic Society. A picture *IS* often worth one thousand words. The painter Georgia O'Keefe said, "I found I could say things with color and shapes I did not have words for."

This is a two inch artist's oil painting brush, called a Hefty. Often a painter will use a broad brush to establish the structure of a painting. An artist is trained to find patterns, to give a work structure, to map it out. It is a process of experimentation, trying out variations; combining, recombining; laying in, scrubbing out, and beginning again. Kind of like what we all do throughout life. Kind of like what learning is all about.

This is what we affectionately call a "yellow box." A National Geographic photographer may fill upwards of fifteen hundred of these boxes on an assignment. That's about forty-five thousand pictures, or approximately one thousand frames for every one published. The yellow boxes contain a record of the photographer's experiments.

Photographers are trained to look at every possible angle. They move around, looking for the best views; left, right, straight on; up, down. A good photographer is like an astronaut, circling around a subject, recording it from every possible perspective.

That kind of exploration and experimentation would not be possible before the invention of the portable 35mm camera.

This diskette is another tool which facilitates experiment and discovery.

The word processor makes it easier for a writer to experiment.

The computer has gotten increasingly visual.

Spreadsheets increase the business analyst's ability to experiment with variations on business models before drawing conclusions and making investments.

Graphics programs let us visualize data.

Geographic Information Systems are a logical extension of the power of the computer as a tool to visualize and understand our world.

What word processing programs have done for writers, they are now doing for students. What spreadsheets have done for business analysts, they are now doing for students. But Geographic Information Systems have, with a few exceptions, not yet had an impact on pre-collegiate education.

You have a critical role. The NSF has a critical role. What you do over the next few days and months will help put these powerful tools into the hands of all our students.

The Society is committed to supporting you in harnessing these powerful learning tools and, most important, getting them into the hands of teachers and students.

Just like the pioneers whose names echo through these halls, you are pioneering the next great improvement in education. Have a good time over the next couple of days. It is very important work that you do.

GIS in Education — A Vision of the Future

by Barbara Buttenfield

Dr. Barbara Buttenfield is Associate Professor of Geography at SUNY-Buffalo, and Research Scientist with the National Center for Geographic Information and Analysis. She has also served at Buffalo as Director of the Geographic Information and Analysis Laboratory. Previously she was on the faculty at the University of California-Santa Barbara and the University of Wisconsin-Madison, teaching courses in analytical and computer cartography, map design, map use, and statistics. Her research interests focus on map generalization and the role of rule-based systems and hypermedia in GIS and spatial decision support.

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Education is a form of communication. Education that utilizes tools for visualization is a form of visual communication. The "dialog" is most often between the student and himself or herself; for example, a student looks at an atlas map, asks a question, and finds the answer on another map in the atlas. Geographic Information Systems in education gives students the opportunity not just to look at maps, but to make maps themselves, intertwining the questioning, the answering, and the map making into a rich educational conversation. The ideal vision for the future is to improve both the visual tools and the students' visual skills, as both can contribute to the educational process.

Elements of Visual Communication

The educational role of GIS is to facilitate the dialog, to make it clear and logical. Four elements can affect visual clarity (or graphical realism) and visual logic (or geographic validity). First, visual resolution affects what can be seen. In terms of size (spatial resolution), the details evident on an aerial photograph (houses and cars) are too small to remain apparent at the resolution of a satellite image. Then too, environmental conditions change seasonally. For example, the sun angle in polar regions is low enough to visually enhance terrain mapping in winter seasons, and thus the temporal resolution affects our vision of the landscape. The spectral resolution is also a factor, since the wavelengths at which geographic information is collected can enhance our vision of phenomena of interest.

A second element is the balance maintained between graphical realism and abstraction, as in a satellite image whose color scheme has been modified so that distinctions between healthy and moisture-depleted vegetation are made prominent. Colors in the image may not appear realistic in comparison with a real landscape, but the color abstraction allows a better view of the vegetation. Ironically, the abstract colors create a view in which geographic patterns are made visible.

A third element relates to visual context. People of all ages have visual expectations about color, size, and spatial orientation. For example, who has not heard the adage that "North is up" on most maps?

Likewise, our vision and understanding of statistical maps lead us to presume that larger symbols represent larger data values, or that the colors red and blue in juxtaposition often represent temperature. Experiments in perceptual psychology demonstrate that the task associated with viewing a picture affects what the viewer pays attention to. Map reading experiments with children show that in the absence of any text, colors are associated with familiar environmental conditions (green shades representing vegetation, for example). In designing GIS tools for education, it is important that system defaults for map drawing and map reading accommodate these contextual expectations and avoid optical illusions that can bias students' interpretation and understanding.

A fourth and final element affecting the clarity and logic of the dialog is proactivity, or the extent to which students interact with GIS visual displays. Proactivity differs from interactivity in the sense that an interactive environment provides capabilities to respond to system dialog boxes and menus, and limited capabilities to take actions anticipated by system designers (e.g., opening and saving files in pre-determined formats, generating displays according to system graphic defaults). Proactive computing environments provide a system responsive to commands and queries that may not have been anticipated by system designers. Multimedia products are beginning to simulate proactivity, and educational products can be found for all ages. Broderbund's *Just Grandma and Me* provides an example for young learners, and Microsoft's electronic encyclopedia *Encarta* provides another. In GIS environments, proactive interfaces have been developed; the ArcView products are one example. A fully operational proactive computing environment incorporates a scripting language that allows users to implement their own commands.

The objective in proactive GIS environments is that all displays appear to lead to other displays and all dialog with the system leads transparently into further dialog. This has obvious applicability for educational environments, where the communication of information needs to be driven by students' curiosity to take actions with consequences. In terms of visual consequences, GIS proactivity allows students to explore landscapes and discover what lies over the next hill. Current technology provides an increasing number of exploratory tools, such as map animation, interactive video, and digital sound that can support or augment realism and logic in educational materials.

Design of proactive materials should follow the same principles as for simple video games. One of these principles is to offer the student immediate involvement and (often) involvement without the need for paper manuals. In contrast to video games, however, the incentive in proactive GIS is that the farther a student progresses, the more that is learned. In video games, it is the converse incentive driving the game (the more one learns, the farther one progresses). Another principle is provision of immediate feedback: students click the mouse and something moves on the screen. A button is clicked and the computer sounds a bell. Students win a video game and achieve a high game score. Proactive learning materials should offer immediate feedback too.

Proactive materials require uninterrupted response, effecting a dialog with what appears to be immediate system response. Video games never make the user wait, and this form of immediate gratification can be carried effectively into a learning environment. Current multimedia products tend to pause, and users wait while software and data are downloaded from a hard disk or network. It is unfortunate that hardware, networking, and technology currently available in many schools cannot support immediate system response. This problem requires attention from GIS system designers and from those who can improve the supply of high-speed technology to support educational computing.

Communicating the Vision

The attitude of many researchers in the GIS community has been that issues of graphical design and graphical communication are not important, not challenging, or not manageable because they are intuitive and difficult to formalize. If visual clarity is taken to mean graphical realism (how realistic is the GIS display) and if visual logic is taken to refer to

the geographical validity of items represented in the GIS display, it becomes obvious that the clarity and logic of the vision will directly guide a student's understanding of geography and the environment.

People believe what they see. If visual information is biased, the interpretation may be similarly biased. The saying "Give someone a fish, they'll eat for a day. Teach them how to fish, they'll eat forever" applies to the vision integrating GIS into education. Showing images, maps, and visual information in the classroom is like "giving someone a fish." It is advantageous to exploit students' curiosity with visual information and beneficial to teach them visual learning skills. This is especially true when the visual information incorporates realism and validity, as it provides an external vision for students.

Using the metaphor "teaching someone to fish" means showing students how to make their own visual displays and how to work with GIS tools directly. It means explaining the four elements of visual resolution, visual balance, visual context, and proactivity, so that students are empowered to tell themselves the visual truth, without imparting unintentional bias to their own interpretations. Additionally, students can learn how to communicate their own internal views, impart their own vision, and test it for realism and validity. This is more empowering in the end, since it teaches students how to educate themselves.

Student as Scientist in the Global Laboratory

by Robert F. Tinker

Dr. Robert F. Tinker is the Chief Science Officer at TERC and President of the Concord Consortium. He earned his PhD in experimental low temperature physics from MIT and taught college physics for ten years. One of the pioneers in constructivist uses of educational technologies, he originated the educational use of microcomputer-based labs and network science. He now leads a number of innovative projects that support hands-on learning for all students at all grade levels. Five years ago his interests extended to the educational applications of GIS.

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I want to express my pleasure and excitement about this conference and about your participation. I know that these beginning sessions are sometimes a little tiring and I will try to be quick and to the point. I want to cover briefly a couple of ideas and launch you off to the real meat of this conference, which is the talking together and sharing.

I have a tool-oriented view of education that goes back to the way I think people really learn. One of the reasons why simply talking (as I am doing to you now) is such a bad way of learning is that everyone comes from a different perspective, with different backgrounds, different knowledge, and different ignorance. The way you learn is right at the boundary between your knowledge and your ignorance. If I tell you about something that is obvious to you, you fall asleep. If I am talking about something that is way over your head, you fall asleep. The boundary layer between those two is often very narrow.

If I give you a flexible tool that you can work with, you quickly zoom up to that boundary layer. You skip over the part you know and come quickly to the place where you need to learn. Students can, by themselves, find the zone where they need to learn. We do not have to develop an intelligent tutor that must discover what kids need to learn and then deliver some appropriate instruction. With a good tool, learning what you need to learn is inherent and natural. That is why tool-based learning is so powerful.

This became very clear to me a decade ago at an international conference where we were demonstrating software and hardware tools. We had a microphone attached to an Apple IIe with signal capture and display software, so that you could look at what you were saying. Some kids approached who spoke only Russian and a few words of English. These kids came back over and over again and kept doing the same thing, which was, at first, incomprehensible to me. They would talk into the microphone and then they would make physical noises—bangs and other sounds. They would talk and they would bang, and they would talk and they would bang. They went at this for 20 or 30 minutes, then one kid looked up at me, and you could just see the light bulbs going off in his head. In fractured English, he said, "Same thing." I did not understand his point, but I was really captured by his enthusiasm and joy. That night I was thinking about his response, and I realized that for this child, for some reason, his zone of learning had to do with the physical nature of sound. He was

incredibly amazed that his speech was in some sense the same thing as other noises, since he had undoubtedly thought of them in two different contexts and had not seen that they were, in fundamental ways, the same.

Tool use is one model for the use of computers in education that is diametrically opposed to so-called intelligent tutors. It seems unlikely that someone designing programmed instruction would ever come up with the misconception about sound, nor could they, having identified it, ever come up with a good way to remediate it. Yet the tool brought the student to this place automatically, without the need for prior "instructional design." To make further progress, this student needed to unify his disparate conceptions about sound, and that is what he learned. He learned something in those few minutes that he is going to build on throughout his life. The next time he runs across a similar tool he will not be working on the same point. He will zoom right past that point and go on to the next layer. Tools permit students to learn at the edge.

I have spent much of my professional life appropriating tools that come from other areas into education. This is a good strategy because almost everything in education has already been done once, usually by Dewey, sometimes even earlier. But Dewey and Tolstoy and other giants of the past did not have computer tools. Because computers have evolved to help us think and plan and solve problems, computer-based tools can offer opportunities to bring to education something that is genuinely new.

At TERC we have had some real successes in the past by pioneering the applications of two important computer-based tools to education. The first involved interfacing computers with laboratory experiments: what we have called MBL, or microcomputer-based labs. The second is in the use of electronic networking for sharing data and creating virtual communities of learners. Networking started at TERC a decade ago and led to the National Geographic Kids Network that George Peterson alluded to earlier.

When I saw Geographic Information Systems about five years ago, it was love at first sight. I see GIS as at least as important as MBL and networking. Without careful analysis of learning theory or anything else, it is clear to me at an intuitive level that GIS tools are neat and that they are the kind of tool that can permit learning at the edge.

Many of the virtues of GIS were alluded to earlier today so I will not spend much time on this, but one point I think worth underlining is that GIS applications are truly interdisciplinary. We just heard Barbara Buttenfield talking about art, basically, but she was also talking about science, about representing data, and about the social studies. Many different kinds of perspectives and disciplines can be united in GIS in ways that are critical in education.

Educators are increasingly concerned about the fracturing of education and about knowledge becoming more and more narrow and contained. We are continually pushed to put more into the curriculum, leading to resistance by educators to anything new, including GIS. But GIS should not be seen as a new topic to be taught. We do not want a GIS curriculum; yet more content for an already overloaded curriculum. GIS is exciting because it is a tool that can be used to teach more effectively what is already in the curriculum, in a way that is visual and interdisciplinary.

The importance of GIS can be traced to its dependence on generating visual images based on heavy computation. There is a lot of data in most GIS applications; typical applications require coordinating several huge databases of three- or four-dimensional data. This computational and display capacity takes advantage of the kinds of information processing in which humans are very able. We take in enormous amounts of information all the time, through visual means, and we abstract meaning from all that rush of data. Meaning can be thought of as distilled data that are reduced by as much as a factor of 10 to the 10th. GIS also provides multiple representations of all these data; a good body of research shows that the ability to generate multiple representations is important in learning. GIS helps provide the capacity to view huge amounts of data from various perspectives and to create understanding, meaning, and knowledge from the data. Since that is the goal of education, this tool must have the capacity to improve education in many dimensions.

I have to share with you just for a minute my own personal dream that can be pulled along and greatly enhanced by GIS. I am not saying that this is THE application of GIS, but it is partly what makes me so excited about it. I see schools as enormously valuable places where environmental research can be done, and I see that, conversely, the involvement in that environmental research by schools can help revitalize education in a significant way. I am deeply committed to the marriage of research and education. The strand of related work that we are doing at TERC involves the Global Laboratory and Kids Network projects. To give you a specific example of the value of environmental research in schools, I will describe a potential project that is an elaboration of Rudy Husar's research on haze. Rudy is here today and has provided a lot of the scientific background.

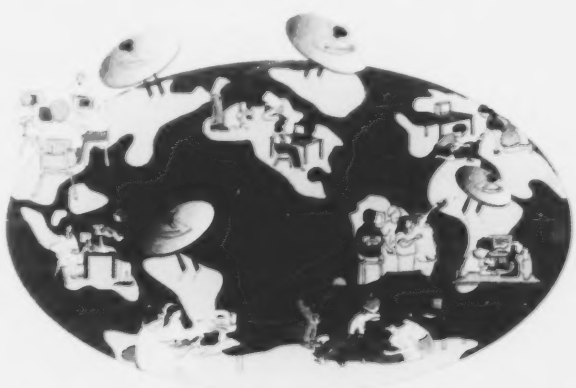
Haze, or suspended aerosols in the atmosphere, has an important potential role in global warming and cooling that has not been nearly as well researched as the role of the trace gases. One of the reasons, perhaps, is that it is very difficult to see haze from satellites, at least the haze that is over land. We have very detailed information about haze over oceans, but not over land. It is quite possible that student-based observations made by simple hand-held photometers could, by looking at the sun at different wavelengths, resolve a lot of unknown information about haze. Haze seems to vary with a spatial variation of about 10 kilometers, so a fairly detailed amount of information is needed. You do not necessarily need stations at every 10 square kilometers because you can combine observations of haze with knowledge of air flow patterns and atmospherics to fill in gaps.

Perhaps a few thousand sites scattered around the United States could give detailed information about haze that would be of tremendous value to the scientific community. Those sites could very well be schools. They could be part of a global laboratory of schools producing data and integrating that production into their learning. The information they generated would not only contribute to haze research, it would permit users to subtract haze from satellite images and improve all kinds of observations based on those images.

The important part of this application is that we do not want to turn students into data robots who are mindlessly going out and very carefully following procedures, yet not knowing what they are talking about and what they are doing. They need to be participating in the effort. They need to be part of the research, not just the technicians. The key, then, is data interpretation. We need a mechanism that aggregates data from many sites, returning them quickly to the sites; the speed of feedback is very important in education. What we dream about is a generalized system that would allow student participation through collecting data, aggregating these data, and returning them to students for analysis. It is the geographic distribution of the sites that is exciting; the data distribution needs to be seen and visualized and worked with, and GIS is the perfect tool. GIS is essential to enable students to participate in a meaningful way in this kind of research.

We are very excited about these ideas and think that if we can only produce the technology and put it in place, we can create a distributed school-based research laboratory that is open to the scientific community. We can show scientists how they can take advantage of this very economically, so that in the not too distant future, when scientists are thinking about how they are going to design a field research program, they will have a new resource to use: a worldwide network of schools with kids who are technically savvy, have the resources and can, in fact, participate in the science and not just collect data.

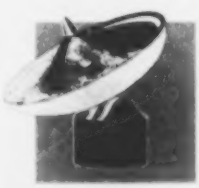
Let me close with a few thoughts about my hopes for this conference. We need to be able to speak to the educational and research communities with a clear



voice. This conference provides a venue to get together in small groups, share our views, and come to a consensus that can provide some leadership. The Internet is a possible model for how best to proceed. I am very impressed, as we all are, with the success of the Internet. Its success is related to a whole new way to do engineering, a model that is diametrically opposed to the big project model that is centralized and top-down. Internet's motto is "Give a little, get a lot." To have an effect in fields where the technology is changing daily, we must cooperate. The field advances when we work together. Together we create a grand vision and then each person or group says: I can contribute to this model. In order to do my work, I need to do this, and then I can contribute it to the whole because I adhere to the standards and the larger vision. That is what I hope happens here: that we can create a grander vision, and we can each see how we fit into it. The goal is not to come up with *the* project that the NSF or NASA or another group is going to fund, but rather, to create a series of ideas that are going to move us in the direction that we need to go.

I know we are going to struggle with long range versus short range. Let me just identify it now and then hopefully it will help simplify some of the discussions. Education proceeds gradually, by a series of small innovations. If you create something that requires big steps, education bangs into those steps and does not go further. Because it is highly decentralized, because funds are always short, because the mission is split into so many different directions, education cannot concentrate resources and make a great leap forward in one direction. So we need to think about the short run; we need to think about the computers that are in schools today and what can be done on computers that are going to be in schools tomorrow. It is frustrating because we can envision a lot of things that we cannot do with the existing technology. We cannot only come up with solutions that require $5,000 per year per station; we have to be sensitive to a series of short-run needs. At the same time, we know the technology is going to change, and in five or ten years our wildest dreams will be commonplace. So it is important to have those dreams and put substance in them, clarify them, and fill them out. When you are doing that, it can be very frustrating to those people who have short-term needs and goals, and it may seem to be almost counterproductive. I think it would be very helpful if in our discussions we are explicit about whether we are taking a short- or long-range view. I think we need both. We need short-term ideas because we need to do that ramping up, and we need the long-range vision to help us understand where we are going.

Do remember as we go along that this is a meeting of people with very different backgrounds, very different concerns, and very different interests. It is going to be a challenge as we proceed over the next two-and-a-half days to keep that in mind. Our fundamental goal is to remember the needs of education, to put the kids on top, as Dan Barstow said. There is a real urgency to this. Anybody who thinks that education is not experiencing serious problems should visit some schools here and in other countries. It is scary; we simply are not putting our best resources into education. We are letting whole generations of kids in the cities lose out. Many educators have been invited to the conference to represent those kids and to keep our discussions centered. I hope those of you who are scientists and software experts listen carefully to these educators.



GIS State of the Art

by Michael F. Goodchild

Dr. Michael F. Goodchild is Professor of Geography at the University of California-Santa Barbara, and Director of the National Center for Geographic Information and Analysis. He received his BA degree from Cambridge University in Physics and his PhD in Geography from McMaster University. His research interests are in spatial analysis, the modeling of uncertainty in spatial data, and geographic data models. Editor of three books on GIS, he is also co-editor of the NCGIA Core Curriculum in GIS, a three-course sequence for upper division college courses that has been the basis for teaching GIS in universities and colleges worldwide.

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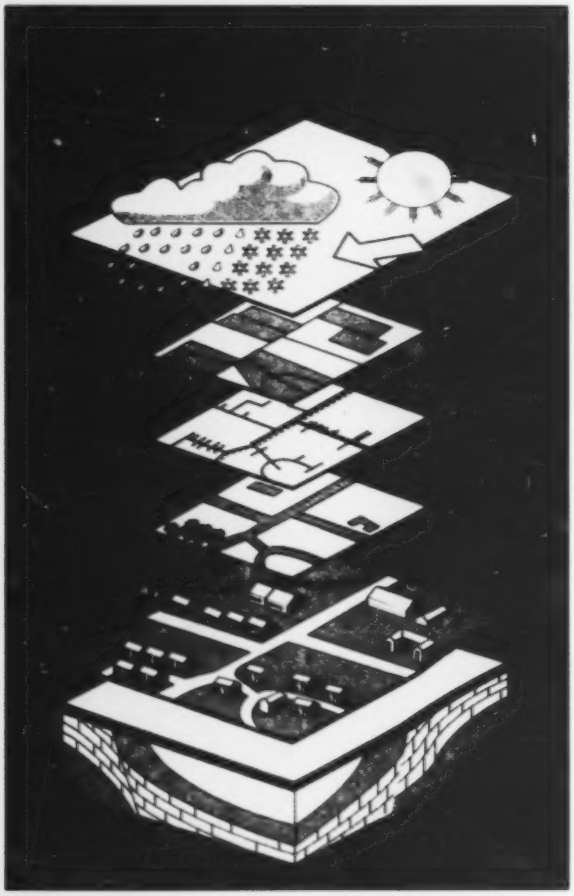
The field of Geographic Information Systems has grown enormously over the past three decades and now comprises many different viewpoints, perspectives, and software systems. In trying to provide a view of the GIS state of the art for educators, perhaps it is most important to stress the key concepts of GIS, how they have been implemented, and for what purpose. What follows, therefore, is one person's view of the key concepts of GIS today and of the issues that currently confront the field.

Perhaps the simplest concept of GIS is that it allows the contents of maps to be stored in computers. If interpreted broadly, maps include not only the conventional paper sheets, but also images of Earth from space, and, more generally, any information tied to specific points on the Earth's surface. Today's GIS can accommodate most types of geographic data, storing them and allowing the user to query and analyze them in a wide range of ways.

Why would one want to store the contents of maps in computers? Most obviously, one could overcome some of the traditional limitations of maps—the frustrations of dealing with places located at the edges of adjacent map sheets, the inability to change scales or "zoom" the problems of navigating with a paper map on which "up" is always North. In principle, a computer display can avoid all these problems. Less obvious, perhaps, is the speed with which one can make maps from data stored in computers, at scales that meet the exact needs of users. Computer data can be edited and updated much more easily than paper maps, and used to manage fast-moving events like the recent fires in Southern California or the Mississippi floods of 1993. We are already beginning to see the advantages of moving geographic data over the information superhighway, with its ability to search for and retrieve relevant information from a vast national and international resource.

A second fundamental concept of GIS is the notion that one can represent the geography of the Earth's surface as a series of layers, each describing the spatial variation of one variable of interest. A GIS database can be built of individual layers of land use, geology, roads, population distribution, or agricultural crops, to name a few of the vast range of possibilities. Each layer is the digital representation of one map, but in combination the layers give a complete geography of a project area—although of course no finite set of layers can ever capture all of an area's geographical variation.

By tying the layers together through common geographic location, GIS provides a unique way of linking data that would otherwise exist in relative isolation. It is often argued that the introduction of a



A GIS image illustrating layers from the GISTutor 2 materials. Courtesy of Longman Geoinformation, Cambridge, England

GIS into an agency leads to a more or less complete reorganization, as links are established between departments and their respective databases through the simple concept of common geographic location.

Related to this second concept is a third, the view of GIS as a new, geographical access path to more conventional types of data. Although this concept is perhaps more mundane than the others, it is nevertheless the major explanation for much of the interest in GIS among utility companies and local government. For example, a gas utility might use GIS to find customer billing records or maintenance data on underground pipes simply by pointing at a computer screen, using the GIS to find conventional database records that have been linked to the map base. The same basic concept is used to find and notify residents living within a certain prescribed distance of a planned land use change, using the simple GIS function of "buffer zone" generation.

Fourth, GIS provides the power to handle vast quantities of geographic information, and thus to avoid much of the need for approximation or generalization that is inherent in conventional map making. A GIS can show geographic distributions in much greater detail than a map or atlas and can also inform its users about the uncertainty present in its data, in ways that go far beyond the techniques available to the map maker.

Finally, and in many ways most importantly, GIS provides a practical means of analysis of geographic information. Maps are notoriously difficult to analyze by hand, and traditional map-measuring devices are crude and imprecise. With the development of GIS has come a renewal of interest in thinking about information in a geographic context and in seeking understanding of the processes that occur on the landscape through a spatial perspective. Analysis can range from simple display and juxtaposition of data, as when a map shows the relative proximities of minority populations and polluting industries, to complex applications of models of environmental processes. The layers of information in a GIS can be used as explanatory factors in studying the distributions of plants or animals. GIS can be used to provide the input data for models of atmospheric circulation and to display the results of simulation. The range of possibilities for spatial analysis is literally endless, and in recent years GIS software developers have added substantial new functionality in this area.

Although estimates vary, it seems that annual sales of GIS software now amount to some $1 billion per year, while the total of all activity related to the collection, dissemination, and use of digital geographic data in the U.S. is worth some $14 billion per year. GIS is clearly a significant sector of the electronic data processing industry, although it may be difficult to define its exact limits.

Despite this level of activity, GIS state of the art is still far short of its potential, in the sense that many important research and development issues remain in the application of computer technology to geographic information. Perhaps most obvious is the fact that GIS remains a technology of maps — and thus predominantly static and two-dimensional. Much research has gone into the problems of handling three-dimensional, time-dependent geographic data, including collection, storage, analysis, and display. But true 3-D stretches the processing capabilities of most of today's computers, and very few truly 3-D data are available.

Another major problem that must be resolved if GIS is to progress centers on data quality. The user of a GIS tends to regard its contents and products as correct, or at least accurate. Maps, on the other hand, are creations of cartographers, designed to give their readers impressions that may be significantly different from scientific truth. It is common, for example, to displace features on highly generalized maps if their symbolic representations would otherwise overlap and thus confuse the reader. Maps are sometimes deliberately distorted or falsified for security reasons.

At one level, GIS can give students a useful lesson in the tensions between scientific measurement and subjective description. More generally, GIS state of the art is rapidly coming to include methods for describing data quality, storing information in the database, visualizing its implications, and propagating it to measures of the reliability of GIS results. Here, and in many other ways, GIS is raising fundamental issues of measurement, information structuring, visualization, and problem solving.

National Science Education Standards

by Angelo Collins

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With the publication of Curriculum and Evaluation Standards for School Mathematics in 1989, the National Council of Teachers of Mathematics introduced the term "standard" into the education reform vocabulary. Since that time, the term has taken on diverse meanings ranging from banners around which reformers rally to hurdles over which students and teachers must leap. Currently there are numerous national as well as state and local education standards projects in many school subjects, including science. The National Science Education Standards Project, coordinated for the science education community by the National Research Council, is defining standards as criteria by which quality can be judged. Standards are statements of what is worth understanding and doing in science.

Standards in science education are being developed for five areas:

Program standards describe how content, teaching, and assessment are coordinated in practice over a full range of school experiences to provide all students the opportunity to learn science.

Teaching standards offer a vision of what teachers need to understand and do to provide learning experiences for all students that are aligned with the content standards. They do not describe one best way to teach.

Content standards define what all students should understand and be able to do as a result of their school learning experiences. They do not define a national curriculum.

Assessment standards identify essential characteristics of fair and accurate student assessment and of program evaluation that are consistent with the content standards at the classroom, school district, state, and national levels. They are not a test.

System standards describe how policies, programs, and actions outside the immediate learning environment support high quality science programs.

Inquiry and the Science Standards

Although the science education standards were not intended to support any given education project, they share a common vision with Geographic Information Systems in several places. The first is in spirit, as the science education standards promote student learning of science through inquiry. The first content standard is Science as Inquiry. In explaining the importance of inquiry, the standards emphasize that inquiry should be recognized as a basic and controlling principle in the organization and experiences of a student's science education. The inquiry standard for grades 9-12 states that all students should develop the ability to:

- identify the questions and concepts that guide scientific investigation
- design and conduct a full scientific investigation
- use technologies to improve investigations and communications
- construct and revise scientific models and explanations using logic and evidence
- recognize and analyze alternative explanations and models
- communicate and defend a scientific argument
- analyze an historical or contemporary scientific inquiry.

The Science as Inquiry Standards for grades K-4 and 5-8 are analogous to the 9-12 standards but focus on experiences that are developmentally and experientially appropriate.

This emphasis on inquiry is a theme in the science education standards. The teaching standards state that teachers should interact with students as they pursue their inquiries and that quality science teacher development requires learning content through perspectives and methods of inquiry. The assessment standards describe a full investigation into a problem of interest to the student as a necessary way to assess student attainment in science. What students should understand about inquiry is described in the Standard on the History and Nature of Science.

In addition to the Science as Inquiry Standard, the Standard on Science and Technology offers useful connections between the natural world and the designed world, and essential characteristics of decision making. These two standards on inquiry and technology are intentionally parallel.

There are still other places where it is easy to see a relationship between the learning experiences and student understandings called for in the science education content standards and the potential for them in GIS. The Earth and Space Science standards call for students to have experiences that allow them to develop understandings of the Earth's history and place in the universe and of biogeochemical processes and cycles in Earth systems. The Life Science standards call for experiences that lead to understanding of populations and their interdependence, while the standard on Science and Societal Challenges calls for experiences that lead to understanding populations, resources and environments, environmental degradation, and global change.

The development of educational uses of GIS that support students' doing inquiry while learning science are consistent with the standards-based educational reform.

Copies of the National Science Education Standards are available from the National Science Education Standards Project (see the section Resources for GIS in Education—Organizations)

National Geography Education Standards

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Geography Standards have just been completed and published. Authorized under Goals 2000: The Educate America Act, these voluntary standards summarize what American students should know about and be able to do with geography at grades 4, 8, and 12. Entitled *Geography for Life*, the standards serve a number of purposes. For example, they guide the development of K-12 curricula and classroom materials, shape preservice education and inservice staff development, and inform university-level geography courses. The title reflects a vision of geography as both a vital academic subject and a necessary and relevant component of global citizenship that can empower the people of the United States throughout their lives. *Geography for Life* has been developed through a broad-based consensus process with input from a wide variety of constituencies.

The Standards have three components: content, skills, and geographic perspectives.

Content—The content of geography is organized around a framework of six essential elements:

- Seeing the World in Spatial Terms
- Places and Regions
- Physical Systems
- Human Systems
- Environment and Society
- Applying Geography

Within this framework, 18 geography standards provide a detailed and full explanation of what students should know and be able to do. Geography Standard One is directly supportive of the mission of Geographic Information Systems in schools:

> The geographically informed person knows and understands how to use geographic representations and geographic tools and technologies to acquire, process, and report information from a spatial perspective.

Skills — The standards present five skills which together constitute a process of geographic inquiry:

- Asking geographic questions
- Acquiring geographic information
- Organizing geographic information
- Analyzing geographic information
- Answering geographic questions

Perspectives — The standards reflect two perspectives central to geography:

- Spatial perspective
- Environmental perspective

Together the content, skills, and perspectives of geography form a framework for *Geography for Life*. Each standard contains between two and four *knowledge statements* that indicate what students should know and understand at the benchmark grades of 4, 8, and 12. *Activity statements* follow knowledge

statements and describe what students should be able to do with geography. The activity statements integrate geography skills, perspectives, and content. *Learning opportunities* illustrate each activity statement and have been included to help curriculum developers, teachers, and other interested individuals implement the standards.

Geography Standards and Geographic Information Systems

Will geography standards provide a context and focus for GIS in elementary and secondary schools? Because the standards have been developed by a consensus process, they reflect the political and educational realities of the United States. Some standards reviewers have criticized the document for not featuring cutting-edge technology, such as GIS. Still other reviewers have criticized the standards for over-emphasizing technology. At numerous hearings teachers, school administrators, and state education officials pointed out that most schools do not have adequate maps, let alone computers.

GIS and associated technologies are featured in several Learning Opportunities and in the Skills component, but not to the degree that many geographers think they should. However, the standards do emphasize developing a spatial perspective, the essence of geography and Geographic Information Systems. They also strongly emphasize doing geography, that is, problem solving with geography, making maps, organizing geographic information, and other kinds of active, experiential learning. These emphases provide a context for GIS, if not a focus.

The geography standards give the GIS community many opportunities, but they do not institutionalize GIS. To paraphrase a well-known statement, perhaps advocates of GIS should ask not what the standards can do for GIS but in what ways the GIS community can help teachers and students to learn the content, skills, and perspectives of geography and become geographically competent.

Copies of "Geography for Life" are available from National Geography Education Standards Project (see the section Resources for GIS in Education—Organizations)

Cognitive Apprenticeship and GIS

by Robert J. Lima

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In the Boshe Institute's Encouraging A Sense of Community: The Design Mentor Program, high school students are teamed with student and professional mentors from various disciplines. Given geographic and other spatial information, the teams must find ways to solve problems arising from real-world case studies in the physical and social sciences. Students and mentors work to understand the scope of the problem and then develop a research design and method that can integrate information from visual and spatial sources with current student knowledge to solve the case study problem. Spatial analysis and integrated learning are the goals of the program, and all spatially referenced data are analyzed by students using manual geographic information processing techniques.

In SIT:UPSS (Spatialists in Information Technology: URISA's Program for Student Studies), the Boshe Institute is joining the Urban and Regional Information Systems Association (URISA) to provide a cognitive apprenticeship environment for students in grades 5-12, designed to facilitate knowledge about spatial analysis and methods for integrating learning across multiple disciplines using Geographic Information System technologies. Faculty, professionals, and students serve as mentors to each other in this program. Spatial analysis and integrated learning are still the goals, but automated geographic information processing techniques are incorporated into the curriculum.

Both programs embody the model of "cognitive apprenticeship" as a way to facilitate spatial learning by pre-college students. Instruction is focused on problem solving with geographically referenced information and relies heavily on curricula that promote opportunities to integrate spatial learning through mentoring between students, faculty, and other professionals.

Cognitive Apprenticeship Model

As defined by Collins, Brown and Holum (1991), cognitive apprenticeship is a model of instruction that works to make thinking visible. In designing effective cognitive apprenticeship environments, these authors advise that the following elements should be addressed:

program content (knowledge required for expertise) — domain knowledge; and heuristic, control, and learning strategies

method (means to develop expertise) — modeling; coaching; scaffolding; articulation; reflection; and exploration

sequencing (ordering of activities) — global before local skills; increasing complexity; and increasing diversity

sociology (attributes of a learning environment) — situated learning; community of practice; intrinsic motivation; and cooperation.

Observations from the Field

Noted below are brief field observations from Encouraging A Sense of Community: The Design Mentor Program.

Student Processes Observed — brainstorming, reconceptualization of a task as a problem, problem definition, development of a research design, identification of critical issues, prioritizing, scenario testing, item analysis, unprompted field surveys to enhance personal/shared database, examination of existing models as a basis for action, consensus building, and proposal/solution development;

Expert Mentor Roles Observed — mentors initially took charge because of their experience, then retreated during the program, affirmed the value of student contributions, provided more questions than answers, shared tricks-of-the-trade, and redirected questions to students for further reflection and analysis;

Institutional and "Soft" Benefits Observed — students became "vested" in learning early in the program, mentors evolved from leadership roles to contributors to observers during the course of the program, students stimulated discussions and actions about the learning environment at their home-base schools (bottom-up motivation for instructional change), and the program was promoted by parents who observed the process.

These observations are part of the Boshe Institute's efforts to incorporate cognitive apprenticeships that facilitate integrated learning using spatial analysis techniques in its pre-college programs.

References

Audet, R., Huxhold, W. & Ramasubramanian, L. (1993). Electronic education: an introduction to GIS. *The Science Teacher, 60,* 7.

Boshe Institute. (1993). *Encouraging A Sense of Community: The Design Mentor Program.* Final Project Documentation - Charette Module. Hyannis, MA: Boshe Institute.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: making thinking visible. *American Educator, 4,* 6-11& 38-46.

Medyckyj-Scott, D. & Blades, M. (1992). Human spatial cognition: its relevance to the design and use of spatial information systems. *Geoforum. 23*:2, 215-226.

URISA. (1994). Have your kids done their SIT:UPSS in Milwaukee? *URISA News, 139*:7.

Wilson, B. G., & Cole, P. (1991). Cognitive apprenticeships: an instructional design review. *Proceedings of Selected Research Presentations, Annual Convention of the Association of Educational Communications and Technology.*

Educational Applications of GIS: A Developmental Psychologist's Perspective

by Lynn S. Liben

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Despite the sophistication and potential of Geographic Information Sytems technology, its educational impact will be minimal unless we take an interdisciplinary approach that recognizes and integrates two sets of links. First, we must address the processes that link the information-to-be-represented and the representation itself. Within GIS, these links are the substantive focus of disciplines such as computer science, geography, or those that develop scientific visualization technology more broadly. Second, we must consider the links between the information-as-represented (i.e., the representation) and the user of that representation. These links are the focus of the discipline of cognitive psychology, and, insofar as the user is assumed to be *changing* over time, the focus of developmental psychology.

Contributions of Cognitive Maturity and Expertise

From the perspective of cognitive-developmental theory (such as that proposed by Piaget), one expects that with increasing age,children will demonstrate increasing levels of cognitive maturity. Neither physical maturation nor exposure to an expanding range of experiences can independently account for this development. Instead, these sources are used by self-regulatory cognitive processes that allow individuals to *construct* increasingly powerful levels of understanding.

This characterization of cognitive development has important implications for the educational use of GIS. Most fundamentally, it points to the need to analyze the cognitive demands of a particular GIS-related task and to ask whether the learner in question has the cognitive prerequisites to understand or learn the task. If the cognitive prerequisites are in place, then the educational task is "simply" one of developing domain-specific expertise. Educators would then provide students with (a) information about the various components of GIS, (b) practice in their use, and (c) opportunities to generalize these skills in new and creative ways.

However, both cognitive-developmental work in general and empirical work on children's understanding of place representations in particular (e.g., Downs & Liben, 1991; Liben & Downs, 1989)

suggest that cognitive prerequisites are often *not* in place at specific ages. Indeed, there is little question that children begin with serious misunderstandings about the basic nature of representations that impede their understanding of GEO-graphics (see Liben & Downs, 1992). Furthermore, there is reason to suppose that many adults harbor serious confusion about fundamental representational and spatial concepts upon which an understanding of GIS rests.

Thus, the educational task cannot simply be one of developing domain-specific expertise. In some cases it may be necessary to begin by developing the learner's cognitive skills before even beginning GIS instruction per se. In other cases it may be possible to develop the necessary cognitive skills in the course of teaching about and with GIS. But in either case the educational curriculum must be formulated with attention to cognitive prerequisites.

Illustrative Concepts and Empirical Data

A structure for the relation between the three most critical areas of cognitive skills and GIS components is shown in Figure 1. Each of the major areas identified as essential—Symbolic, Spatial, and Logical—subsumes a number of specific concepts. Each concept may be relevant to one or more components of GIS—input, analysis, or output. Its relevance will depend upon factors such as whether the focus is on consumers versus developers of GIS, or on whether the GIS output is or is not in spatial-graphic form (the contrast between map and textual GIS output). Space constraints allow only one conceptual example applied to only a single GIS component.

Symbolic Concepts: Relevance for Understanding GIS Output

To adults—particularly those who work with sophisticated representational media such as maps and GIS programs—symbolic concepts seem "obvious." Adults may assume that they are equally obvious to all GIS users, but there is ample evidence from developmental psychology that children do not understand even the most fundamental nature of symbols (Liben & Downs, 1992).

COGNITIVE SKILLS	GIS COMPONENTS		
	Data Base	*Analysis*	*Output*
Symbolic			
•			
•			
•			
Spatial			
•			
•			
•			
Logical			
•			
•			
•			

Figure 1. Structural Matrix Relating Cognitive Skills to GIS Components

One symbolic concept that has been shown to develop only gradually is understanding of the arbitrary nature of symbols. Young children mistakenly infer that qualities of the symbol necessarily mean something about the qualities of the referent, and the reverse, that qualities of the referent must be mirrored in qualities of the symbol. As an example of the former, we have found that young children believe that a road shown by a red line on a map means that the road for which the line stands actually is red; as an example of the latter, we have found that young children will reject an area on a black-and-white aerial photograph as showing a field of grass "because grass is green."

Nor are adults entirely immune to this problem, as illustrated by the well-known confusions created by Vignelli's 1977 New York City subway map in which the Hudson River was depicted in brown rather than blue. Comparable confusions have been found with respect to the shape and size of symbols and referents as well as their color. The relevance for this confusion for GIS is readily apparent: one cannot assume users will automatically understand the symbolic nature of GIS output that might seem patently obvious to a GIS expert or educator.

Spatial Concepts: Relevance for Understanding GIS Input

As part of a theory of the development of spatial cognition, Piaget and Inhelder (1948/1956) noted that an advanced achievement is the ability to use abstract, stable reference systems such as a Cartesian coordinate system. One indication of individuals' abilities to use a horizontal-vertical coordinate axis system is whether they can perceive and represent everyday horizontal and vertical invariants. In the water-level task, the subject is given an outline drawing of a tilted bottle and asked to draw a line to show where the water would be if the bottle were about half full. Piaget's original reports showed that the majority of young children fail these tasks. Recent investigators have found that even large proportions of adults (as many as 30-40% in some samples) have difficulty as well (Liben, 1991). A sample *adult* response is given in Figure 2. If many individuals are unable to use an abstract, stable reference system, they may be expected to experience difficulty in understanding the locational structure by which data are entered into the GIS database, and thus in understanding the basis of the entire system.

Figure 2. Sample adult response to the question of where the water line would be if a tilted bottle were half full.

Logical Concepts: Relevance for Understanding GIS Analysis

Among the logical skills studied in cognitive development is the ability to understand class inclusion. Understanding the hierarchical nature of superordinate classes and their component subordinate classes allows one to answer questions such as "If all the birds were to die, would there still be any robins left?" Extensive research (Piaget, 1941/1965) has shown that children in the early elementary school years fail such questions. Again, it is simple to see that a failure to understand class inclusion would be problematic for understanding even the simplest geographic or GIS analyses (Downs, Liben, & Daggs, 1988) that make use of hierarchical class relations (as in analyzing data using ever-expanding units such as street, town, county, etc.).

As is appropriate for a publication concerned with educational applications of GIS, this essay has implicitly assumed that GIS skills are the educational *outcome* of interest. Given this assumption, underlying cognitive skills are conceptualized as *prerequisites* or *mediators* that, when necessary, may need to be enhanced enroute to GIS mastery. It is important to recognize, however, that the perspective could be reversed. We could instead ask how GIS instruction may be used as a *means to develop* underlying cognitive skills. As we begin to formulate curricula, we should remember that the educational highway can be a two-way street.

References

Downs, R. M., & Liben, L. S. (1991). The development of expertise in geography: A cognitive-developmental approach to geographic education. *Annals of the Association of American Geographers, 81*, 304-327.

Downs, R. M., Liben, L. S., & Daggs, D. G. (1988). On education and geographers: The role of cognitive developmental theory in geographic education. *Annals of the Association of American Geographers, 78*,680-700.

Liben, L. S. (1991). The Piagetian water-level task: Looking beneath the surface. In R. Vasta (Ed.), *Annals of Child Development* (Vol. 8, pp. 81-143). London: Jessica Kingsley Publishers.

Liben, L. S., & Downs, R. M. (1989). Understanding maps as symbols: The development of map concepts in children. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 22, pp. 145-201). New York: Academic Press.

Liben, L. S., & Downs, R. M. (1992). Developing an understanding of graphic representations in children and adults: The case of GEO-graphics. *Cognitive Development, 7*, 331-349.

Piaget, J. (1941/1965). *The child's conception of number.* New York: Norton. (Original work published 1941 as La genese du nombre chez l'enfant.)

Piaget, J., & Inhelder, B. (1948/1956). *The child's conception of space.* New York: Norton. (Original work published 1948 as La representation de l'espace chez l'enfant.)

A Convergence of Themes in Educational Reform

by Richard Audet

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If it can be said that nothing is more powerful than an idea whose time has come, then it may be informative to reflect upon why the time for applying Geographic Information Systems to education has apparently arrived. What stimulates a significant number of individuals to simultaneously conclude that using GIS for educational purposes is an issue that warrants serious examination?

The interest in pre-college GIS education manifest in the calling of this conference may be attributable to the convergence of several educational trends. No claim is made that the following list is exhaustive; rather, it synthesizes my considerable reflections on why the moment seems ripe for inclusion of GIS-based curriculum materials in America's schools. Although these comments are clearly an example of preaching to an audience of the converted, a convincing argument can be made that educational applications of GIS and the themes below are presently traveling on parallel tracks.

Theory of Learning—Constructivism has emerged as the dominant framework for discussing cognition. Armed with this conceptual underpinning, we can design curriculum and instruction that are complementary to how people learn. Newly redefined education roles are student as worker and maker of meaning, and teacher as mentor and facilitator of learning. Since few secondary-level GIS materials exist, it provides a golden opportunity to create state-of-the-art educational packages that incorporate much that is known about learning, teaching, and curriculum design.

Collaborative/Cooperative Learning—Educational reform movements stress the need for creating classrooms that are more student-centered. Cooperative learning has emerged as a popular strategy for accomplishing this goal and for addressing the inequities that frequently arise from ability grouping. GIS is a natural vehicle to support team learning.

Project-based Learning—Cooperative learning has been found to produce optimal results when activities are structured around a project-based curriculum. Learning programs that promote problem solving are ideally supported by an integrated GIS component. With the support of GIS, open-ended inquiry becomes a realistic goal of instruction.

Authentic Practice—Educational experiences that are anchored in real-world contexts are becoming more common in schools. The motivational aspects of "learning locally, thinking globally" are self-evident. GIS makes locally based learning possible. Generic curriculum materials can be tailored to any learning location with pre-packaged, site-specific data sets in CD-ROM format or via a telecommunication line.

Integrated/Interdisciplinary Learning—Major educational reform movements are unequivocal in their endorsement of integrated approaches to curriculum development. Traditional subject boundaries are weakening. GIS naturally provides a bridge for linking information from various disciplines, such as biology and geography.

Performance Assessment—Alternative measures of student performance are under heavy scrutiny. Students are expected to be able to demonstrate their learning. Some teachers are experimenting with electronic portfolios, collections of students' work that are compiled in a computer. With a project-based curriculum supported by GIS capability, proof of student learning lies in the product of the group's effort.

Learning Styles—Ample evidence demonstrates the existence of a variety of learning preferences. These individual orientations are powerful influences on how a person learns. GIS can be a special tool for helping visual learners.

Environmental Education—Survey results consistently demonstrate that environmental issues are important to young learners. The power of GIS as an educational tool stems in part from its ability to allow students to manipulate massive amounts of authentic data to investigate issues of local concern. Education becomes more meaningful as the content for learning becomes more personally relevant.

Collaboration—Because of a concern with the need to improve our educational system, most sectors of society are engaged in efforts to remedy the problem. The convening of this conference makes a statement about the common interests of industry, government, and the educational communities in working toward shared goals. The intense expansion of telecommunication can be expected to provide a link for expanding the scope of initiatives among these groups.

Advanced Computer Capability—As computer availability expands and interactive software changes the nature of computer-aided instruction, computers as tools for learning appear to have come of age. Students learn with the computer and not necessarily from the computer. GIS is a tool for supporting an environment that provides open-ended opportunities for learning.

Questions to Consider

Planning conferences such as EdGIS are likely to generate as many questions as answers. Among the issues that may arise are the following:

1. Where does a GIS education initiative fit within the context of systemic educational reform?
2. What do we know about spatial learning in children?
3. How can the level of awareness of GIS in the educational community be raised?
4. What will be the development model for preparing GIS curriculum materials?
5. Will an optimal instructional delivery system be identified for GIS education?
6. How will teachers be trained to use this technology in their classrooms?
7. Is the general availability of computers adequate to support a major GIS educational tool?
8. Will the availability of digital data increase?
9. Will the cost of acquiring data fall to acceptable levels?
10. Who will ensure that these and other questions that emerge during the debate are properly addressed?

The Cutting Edge

Some Current Initiatives

NCGIA Secondary Education Project

by Stephen D. Palladino

As the Education Projects Manager for the National Center for Geographic Information and Analysis, Stephen D. Palladino coordinates Geographic Information System activities for primary school through graduate studies and beyond. He spent four years teaching advanced math in a Los Angeles County high school and presently teaches geography at Santa Barbara City College. His Masters in Geography degree is from the University of California, Santa Barbara.

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The National Center for Geographic Information and Analysis (NCGIA) was established by the National Science Foundation in 1988. The NCGIA is a consortium of the University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine. The Center's mission reflects the desires of the NSF: to advance the theory, methods, and techniques of geographic analysis based on geographic information systems in the many disciplines involved in GIS-based research; to augment the nation's supply of experts in GIS and geographic analysis in participating disciplines; to promote the diffusion of analysis based on GIS throughout the scientific community, including the social sciences; and to provide a central clearinghouse and conduit for disseminating information regarding research, teaching, and applications.

This mandate is carried out by a series of research initiatives, education activities, and outreach efforts. Early education activities were focused on supporting GIS-related instruction at the postsecondary level. As the NCGIA developed materials for the postsecondary level, input from various sources suggested that GIS might have a place within K-12 education. With GIS software for personal computers becoming more common and a corresponding increase in personal computer power and reduction in price, it was reasonable to imagine GIS use in the schools. These factors led the NCGIA to establish the Secondary Education Project (SEP) during the 1991-1992 academic year.

Secondary Education Project Goals

- Locate existing GIS activities in the schools
- Serve as a link between these various activities
- Investigate the potential uses of GIS in the classroom
- Identify existing GIS materials for the schools, including appropriate hardware and software
- Provide support activities (workshops and materials development)
- Communicate progress and possibilities.

Project Activities

The first major activity of the Secondary Education Project was to hold a fact-finding, prototype GIS workshop in 1992 for secondary school teachers. Ten science, social studies, and computer studies teachers selected from local schools attended the one-week workshop and received an immersion in GIS concepts and practice. They in turn reflected on the potential for GIS in their teaching. Although significant impediments to easy adoption were identified, the teachers were unanimously supportive of GIS use in the schools.

As a result of this workshop, a Workshop Resource Packet was designed to support "GIS-rich" organizations and higher education institutions in doing GIS outreach to the schools. The Packet includes the review of the prototype workshop, teacher project summaries, a model workshop format, the short course notes, a resource list, and a simple GIS glossary.

With help from the IDRISI Project, the SEP put together sets of digital data on Africa to create an African Data Viewer in 1993. The Viewer allows the user to view the images of various thematic characteristics of Africa with the IDRISI software's display modules which are included on the disk (see "IDRISI"). This data set serves as an introduction to digital data as they would appear in a GIS package such as IDRISI.

In the summer of 1993, both the California and Maine sites of the NCGIA held one-week GIS workshops attended by geography, earth science, and computer applications teachers. Participants received a short course in GIS (10 hours of basic information about GIS and how it works); viewed GIS demonstrations by researchers using GIS; and used various GIS software packages, including ArcView, IDRISI, AEGIS, Atlas*GIS, MAP II, and GISTutor. Discussions of GIS in schools covered the use of computers, where GIS would fit in the curriculum and in specific courses, opportunities, obstacles, and modes of teaching. Participants planned how they might use GIS in their classrooms and in inservice and collaborated on a group project, using ArcView in Maine and IDRISI in California.

Workshop Findings

Presentation and analysis procedure in a teacher workshop on GIS.

One of the subjects explored during the teacher workshops was the potential benefits of GIS-based learning activities. The teachers felt that GIS:

- Exposes students to maps and other geographic data and is therefore an excellent base for geography studies
- Emphasizes spatial analysis (this is GIS's forte)
- Enhances critical thinking/problem-solving efforts
- Introduces students to high technology
- Demonstrates a practical use of computers
- Builds project management and group working skills
- Supports exploration of environmental issues
- Exposes students to the job market
- Serves as a stimulus for higher education.

During the workshop the teachers discussed the courses that might support GIS activities. They were able to link GIS to many disciplines, such as: geography; life, physical, and earth sciences; environmental studies; ecology; oceanography; geology; biology; history; political science; economics; computers; business; and vocational education.

Another subject probed by the teachers was the range of GIS or GIS-allied activities they might try in the courses listed above. Strategies they identified include:

- Preparatory map learning—may be necessary before initiating GIS activities or perhaps GIS can be used to teach map skills
- Visual introduction—slides, videos, posters, magazines
- "Manual" GIS—overlay overhead projector transparencies, worksheets using GIS concepts
- Guest speakers—GIS users from university, government agencies, and businesses
- GIS demo packages and pre-GIS packages, such as PC Globe, AutoMap, electronic atlases that may help present GIS concepts and lead into GIS
- GIS education packages—hypertext, specially written tutorials, exercises, and even software
- GIS database and quick analysis support for classes
- GIS group projects—teams attempting to use GIS to solve problems or looking at/creating/analyzing data combinations
- Independent GIS projects for advanced students, science fairs.

These activities fall on a continuum of increasing reliance on the GIS technology and concepts. As the teachers pointed out, the specific circumstances of each class greatly affect which level of GIS activity is attempted. The levels of use for GIS software and concepts range from simple "show and tell" to fully developed GIS projects. The base level, mentioning GIS where contextually appropriate, was seen as a common denominator. The next level, describing the technology and its applications in more detail, especially by means of visual presentations, was seen as viable in most classrooms.

Teachers or guest speakers can demonstrate GIS software, demo packages, or pre-packaged modules. As GIS moves to a significant role in instruction, the "teach with" and "teach about" levels are reached, reflecting two modes of GIS-based educational activities: "GIS in education" and "GIS education." It is necessary to teach about GIS in order to realize the highest level: using GIS software to work through a particular problem.

Within each level, varying amounts of GIS-based learning can take place. For example, teaching with GIS modules designed to enhance the existing curricular objectives (e.g., the study of earthquake location with relation to tectonic plate boundaries in an earth science course), the teacher might try a GIS-based lesson once or use GIS-based materials as a regular part of the course.

Conclusion

The SEP activities of the past two years have only confirmed what many knew intuitively — GIS has definite potential for pre-college education; in fact not only in secondary schools but in grades K-6 as well. The question is not whether GIS has a role in the schools, but when and how it will be best manifested in that educational environment. Is GIS still too complex conceptually and materially for serious use in the schools? As with many important questions, the answer depends on the perspective of the respondent.

The results of our research indicate that the questions of when and how are still to be resolved, but an initial GIS presence in the schools is appropriate now. The question of when will be better answered in the context of efforts to resolve key issues in the use of GIS in the classroom. As these issues related to technology (hardware and software) and the education and scientific communities (data, curriculum materials, teaching and learning strategies, understanding and adoption, and support structures) are resolved, the impact of GIS on the schools will increase significantly.

Information about NCGIA and its Secondary Education Project are available from National Center for Geographic Information and Analysis (see the section Resources from GIS in Education—Organizations)

GIS in a Geosciences Curriculum

by Kathryn Keranen

Kathryn Keranen is a geoscience instructor at Thomas Jefferson High School for Science and Technology in Alexandria, Virginia. A classroom teacher for 23 years, she became involved with GIS when she came to Jefferson and the geoscience department was trying to incorporate it into the curriculum. She is now responsible for the school's geoscience lab and works in close association with the US Geological Survey.

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Seniors in the geoscience course at Thomas Jefferson High School for Science and Technology get their first taste of Geographic Information Systems by constructing a digital elevation model of a hill on the school campus. After they make an initial raster image of the hill with appropriate documentation, the sidewalk at the bottom of the hill is digitized, rasterized, and overlaid to show only the elevations of the sidewalk. Vegetation polygons are also included. The project is assessed entirely on the production and documentation of the raster image of the hill, the vector and raster image of the sidewalk, and the final overlay of sidewalk showing the elevation.

As the lead teacher chosen to spearhead this new technology, I received two days training. We chose to use IDRISI software in our lab (which has several PC-compatibles 286 and 386) because of its relatively low price and low learning curve. No matter what GIS software package is used, students need to know the concept of GIS, how to enter data into a GIS, how the software displays the data, and they need to have an understanding of the documentation of each image.

After the students are comfortable with the basic concepts, the use of GIS as a geoscience tool continues throughout the curriculum. An extensive unit on remote sensing data and its use in solving problems is included. Landsat data are imported into IDRISI, and supervised and unsupervised classifications are done. We have used Landsat images of the 1988 fires of Yellowstone, the fires of Kuwait, and the Mississippi flood.

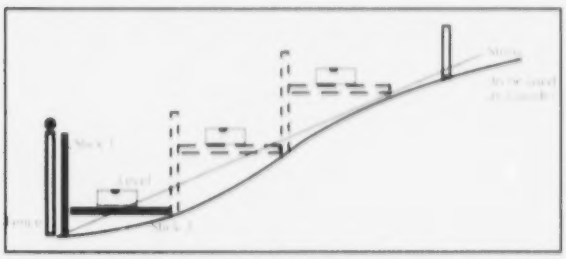
Students from Thomas Jefferson High School for Science and Technology take measurements of a hill on campus to be used with GIS tools to construct a digital elevation model.

It is important to note that we are not teaching GIS by itself but utilizing it as a tool to be incorporated into a conceptual science curriculum. So many of the concepts of geoscience can be studied and analyzed using a GIS platform that it is a great place to integrate this new technology.

In addition to all twelfth grade students using GIS throughout the year, a number of students have done independent GIS projects. Last year as a culminating project students were asked to develop a complete analysis and proposal for a solid waste disposal site

in Fairfax County, Virginia. One of the students, Tyler Moeller, made use of all the currently available GIS capability of the school to complete his project, which was highlighted at Vice President Gore's Performance Review at the U.S. Department of the Interior.

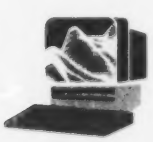
Because Thomas Jefferson High School has a working agreement with the U.S. Geological Survey to experiment with making data available on the Internet and to allow us to use their ArcInfo software, Tyler used a digital line graph, digital elevation model, and land cover data to prepare a map of the landfill site. He partitioned the file into smaller coverages that were useful for the project, ran display applications, and then plotted his map in our AutoCad lab.



Student Tyler Moeller developed this drawing as part of a map of a landfill site.

Tyler's project demonstrates the importance of GIS technology and electronic transfer of digital data in instructing students in earth science. Currently we are trying to develop a methodology for entering field data into an existing GIS database. USGS is giving us access to a GIS database of the Difficult Run Watershed in Fairfax County. Using ArcView (which was given to us by its publisher, ESRI) we are first trying to understand the database and new software and then will try to begin a field component to our studies by developing a way to enter water quality and other environmental measurements. Stay tuned!

Asked to describe an ideal situation, I envision geoscience as a senior problem-solving class with GIS as the tool that is constant throughout. The course would start with local problems (community GIS databases), move to a regional remote sensing database, and end with a global perspective. The curriculum would be assessed by the solution of problems, the display and analysis of data, and the communication of conclusions. Specific needs would be curriculum data sets, training, and a harmonious team. I'll keep working toward this ideal.



Urban Environmental Education in Detroit

Randall E. (Randy) Raymond is the Project Director of the Urban Environmental Education in Detroit Program at Cass Technical High School in Detroit, Michigan. Involved in teaching and environmental research for the past 22 years, he began his professional career as a research scientist working on watershed management studies for the W.K. Kellogg Foundation.

by Randall E. Raymond

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My students at Cass Technical High School in Detroit, Michigan, are soon going to learn a great deal about lead pipes and water. They are beginning to create a map of the 200,000 homes in their city that have lead pipes leading from the water main in the street to the water service in the houses. In collaboration with the Community-Based Health Program of the University of Michigan's School of Public Health, they have recently embarked on a major GIS management project: they are mapping the location of all the homes—which include ones where lead levels are 400 times the EPA-accepted levels—and integrating this information with the GIS map layer that identifies the location of all 261 school buildings in the city. The students will use the demographic data available to identify similar neighborhoods in Detroit which vary in terms of lead pipe water service. This information will be used by the Detroit Public Schools to investigate standardized test scores of elementary school students from neighborhoods with and without lead pipe. Neither the City of Detroit nor the School of Public Health have had this capability before their collaboration with the GIS program at Cass Technical High School. Students will be paid for the time they spend on the data preparation and analysis. How did this all get started?

Student Andre Broughton points out an area of interest in Southeast Michigan GIS map examining the relationship between individual income and educational attainment levels.

It began with students participating in the school's Urban Environmental Education in Detroit (UEEID) program. There the students study and explore the quality of their urban environment, learning how to teach activities rich in science and mathematics applications that involve environmental and outdoor education topics. Observing how the conditions of a neighborhood may contribute to success in school, the students began to wonder how the UEEID program might be modified to involve them more in the revitalization and regrowth of their city. Soon after,

we decided to provide students with educational experience in the use of Geographic Information Systems and to forge community and business partnerships that offer these students an opportunity to assist in the development of preparation strategies using GIS mapping information systems.

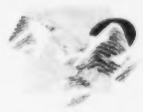
Through the UEEID program and, specifically, the Urban Education Resource Center, the students at Cass Technical High School became among the first in the nation to have educational experiences using GIS systems at the secondary level. The Resource Center provides introductory and advanced GIS training for 11th and 12th grade students and for adult education. Through an internship network, students trained in GIS during the summer and school year are able to experience first hand the applications of GIS in government and industry. The students provide GIS services to the community through varied education activities, including demographic studies for small businesses, resource mapping and planning for local units of government, and design of school transportation systems accessible to all students.

The current teaching of GIS in the high school program makes it possible to increase students' understanding of the complex nature of environmental problem solving in the urban community while providing them with technology skills and experiences that enable them to serve as a valuable resource to many segments of the community. Collaboration with the University of Michigan's School of Public Health is the latest example of the kinds of cooperative and collaborative partnerships that have been formed with numerous organizations.[1] Twenty-six possible GIS projects have been indentified in the School of Public Health's program alone. Working with such partners allows UEEID students to interact with individuals and organizations in the community in need of information processing and spatial data analysis. UEEID is able to develop further its community outreach by providing valuable information services important to the successful revitalization of Detroit. Each of the agencies in turn provides a set of connections to other real-world programs and problems in which the students can get involved. Through this education/community outreach program the Detroit Public Schools system becomes a part of the community rather than apart from the community.

We need to do away with textbook education and move toward technological education. We have looked too long at the 21st century as a place where we are going to arrive. The future begins today, and the education we give our students is the future. It is time we recognize the value of the students in our high schools and allow them the opportunity to contribute to the solution of real-world problems as they learn to interact with new and expanding technologies. Using GIS systems that focus the students' learning activities in their own communities and make it possible for them to make valuable contributions to the revitalization and regrowth of those communities is important to the education of all children no matter where they live, be it rural, suburban, or urban.

[1] Including Central Business District Association of Detroit, Friends of the Rouge - Interactive Watershed Water Quality Monitoring Program, Eastern Michigan University, Southeast Michigan Regional Groundwater Education in Michigan Center, University of Michigan - Dearborn, National Wet Weather Rouge River Remedial Action Council, National Tech Team Computer Training Corporation, and Environmental Systems Research Institute.

National Student Weather Network



by Donald P. La Salle

Dr. Donald P. La Salle is the President and Executive Director of Talcott Mountain Science Center for Student Involvement, Inc., in Avon, Connecticut. The Science Center is a regional nonprofit educational and research facility dedicated to increasing students' and teachers' awareness, understanding, and appreciation of their physical world. Dr. La Salle's contributions to education include SciStar, an interactive satellite television program featuring renowned science experts; Project PROMMISE (science role models for minorities); and the National Student Weather Network.

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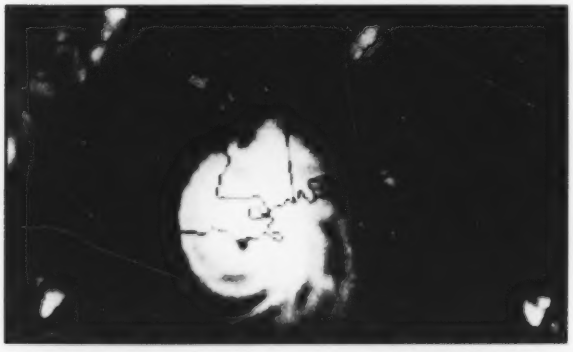
The National Student Weather Network enables students to learn about the weather, to experience science in a real-world context, to experience telecommunications, and to develop skills of collaborative investigation. It has succeeded beyond our expectations in all four of those goals.



Hurricane Andrew—one of the images studied by students in the National Student Weather Network. Image created using Accu-Weather Forecaster.

Conceived by the Talcott Mountain Science Center in 1989, the National Student Weather Network builds on the base of weather education provided by the Science Center. Throughout its 25-year history, the Science Center has operated a student and teacher Weather Center, equipped with the latest hardware and software to access live weather data and images from around the world, and complete with its own Doppler Color Weather Radar.

Funded by the U.S. Department of Education, the National Student Weather Network provides multi-dimensional weather education for approximately 5,000 students in 200 participating schools throughout the country. Participating students are able to access live weather data in their classrooms, analyze the data using a variety of maps and image tools, and make local forecasts. They also use a set of weather instruments to do their own local weather observations, which they share with their peers using computer telecommunications. Finally, students participate in a weekly satellite television broadcast that helps them learn basic concepts of meteorology based on the actual current conditions.

Perhaps the best way to describe the Weather Network is through an example of a typical day at a participating elementary school in Hartford, Connecticut.

When they arrive at school, a group of five students in Mrs. Rivera's class take their weather instruments from the classroom and go outside to make their morning observations. First they use their own observations to determine some of the current weather conditions. They record, on their daily weather record chart, the percentage cloud cover, the type of precipitation (if any), and the estimated wind speed. Next they use the hand-held barometer to record the barometric pressure and a digital thermometer for temperature. They check their permanently mounted rain gauge for precipitation in the last 24 hours. Finally, they use an inexpensive digital sling psychrometer (designed by Talcott Mountain staff and built by the students) to determine humidity level.

When the students go inside, they start the Accu-Weather Forecaster software and enter the data into the student weather entry form. They then have the computer automatically send their data to the central data base and automatically access the latest National Weather Service data and images. This is all done in the half-hour before school starts (students are eager to be the "weather kids" of the day).

Students at Talcott Mountain Science Center taking weather measurements as part of the National Student Weather Network

Meanwhile, other students throughout the country are engaged in the same process of recording local conditions and transmitting them to the central student weather database. This central database, called DataShare, is operated and maintained by the Accu-Weather company as part of its involvement in the Weather Network. Once all the student reports have been received, the schools can reconnect with Accu-Weather to download the consolidated student database.

It is now time for Mrs. Rivera's daily weather class. She teaches weather as a six-week unit each year, participating in the Weather Network during that time and using the curriculum materials provided by Talcott Mountain. She has the day's "weather kids" report on their local weather observations. Then they use the computer and the Accu-Weather Forecaster software to display and analyze both the National Weather Service data and the Student Weather Network data. The NWS data have the advantage that they are available every hour, every day of the year. On the other hand, the Student Weather Network data have the advantages that students feel a direct personal connection with the data, and in some areas of the country they are able to get even greater resolution than the NWS. For example, there are 6 NWS stations in Connecticut, and roughly 20 schools in the Student Weather Network.

In the "GIS component," the students analyze the data using the mapping tools built into the software. They are able to display any of 10 types of weather data as values on the maps, zoom in to any region of the country, automatically draw shaded or color contours, and examine satellite images and radar scans. They also are able to compare their own data with the NWS data. Our experience is that students are readily able to master the use of the mapping tools, especially because there is such a real and immediate purpose to their explorations.

As a result of this weather map exploration, the students develop a better understanding of their local weather conditions and make their own forecast for the next day. Students can also use e-mail to contact the other participating schools if they want more information or want to share their analysis with their partners in this network.

One of the challenges for the teacher is to be able to teach basic concepts of weather based on the current conditions. For example, the temperature contour map might show a dramatic frontal boundary between a cold mass and a warm mass — and therefore the teacher should "seize the teachable moment" and explore this aspect of the weather with the students.

In order to help the teachers do this, Talcott Mountain provides several teacher training workshop opportunities during the year, as well as curriculum support materials that are designed to support this kind of flexibility for teaching particular concepts based on current conditions. The materials focus on a manageable core set of weather concepts and activities. However, we also make clear to the teachers that exploring and learning with their students is a powerful and desirable approach to teaching. They do not have to master the content of meteorology before teaching this class. Rather, we encourage them to say "I don't know, let's explore and learn together."

On this particular day of the Weather Network, the Talcott Mountain Science Center also provides an additional support for the students and teachers—an interactive television program that is nationally broadcast by satellite and cable TV. Produced in the video studios of Talcott Mountain, the weather program features presentations by its staff on basic weather concepts, based on the current conditions and the student-submitted data, with the opportunity for students and teachers to call in and ask questions or report new information.

Throughout the six-week unit, Mrs. Rivera takes advantage of the students' enthusiasm for the weather to tie in with other subjects, including math (graphing data), language (writing letters to the other schools), history (impact of weather on local history), art (drawing pictures to illustrate the forecasts), and career awareness (inviting a local TV weather forecaster to the class).

The National Student Weather Network is open to classrooms anywhere in the US. We are always eager to have additional classes join the network, both for their own educational benefit and to enrich the network for everyone.

GIS and Environmental Education

by Reinhold Friebertshauser

Reinhold Friebertshauser has taught geophysical science, geographical information systems, and other courses at University School in Ohio for 10 years. He is currently involved in developing collaborative projects involving schools and public and private organizations, and in establishing a summer research institute for the study of the Chagrin River watershed that will build and maintain a Geographic Information System.

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Terry Harmon, a science teacher at the University School in the Cleveland, Ohio, suburb of Hunting Valley, has used the 200-acre campus and 5-acre lake as a unique outdoor classroom for the past 20 years. Activities at the independent preparatory school for boys include a student-operated brook trout hatchery (now certified by the state of Ohio to breed a recently discovered native breed of trout and repopulate suitable streams), a maple syrup industry that taps 600-1000 trees, and a forest management program that cultivates new trees and provides lumber for the school's woodshop classes.

Three years ago, Terry and two other teachers, Reinhold Friebertshauser and Pat Barnes, discovered GIS technology and saw in it a powerful tool for teaching students and teachers to collaborate in the struggle to understand increasingly complex environmental problems. Using the school's 200-acre watershed as a microcosm for larger systems, they initiated a Geoscience course with the intent of integrating abstract learning, technology, and practical field experience. The course description notes that "we will deal with the most theoretical of issues, but we will get our hands and feet dirty in the process."

University School students Mark Hogan and Kevin Kelly and instructor Reinhold Friebertshauser combine traditional surveying and modern GPS (Global Positioning System) methods to develop a digital elevation model of the bottom of University School's 5 acre pond.

Forty-four boys from grades 10 through 12 have been involved in the project to date. They meet an average of 1-1/2 hours per day and focus their attention on two major components, one global in its scope, the other local.

The first component involves a survey of various types of scientific data and methods of analysis used to study the earth system, including the traditional disciplines of geology, geography, cartography, surveying, ecology, and meteorology. Also included is an introduction to the use of the computer as a tool for scientific investigation. Students are exposed to

remote sensing, digital elevation modeling and GIS, using software that includes AutoCad (rel.12), Quicksurf from Schreiber Instruments, ArcView, ArcCAD, ArcUSA, and ArcWorld from ESRI, and IDRISI from Clark University.

The second component applies this background to the local environment. The team of teachers and students turn to the study of the school's watershed and the ongoing development of a local Geographical Information System. Data are collected on: stream flow; water and soil temperature; water quality; dissolved oxygen; soil characteristics, including moisture, texture, pH, and calcium; forest and lake productivity; vegetation cover; topography; land use; and weather data from a computerized weather station.

These data are added to map layers using the GIS software. Once these features are spatially related, students can begin to look at relationships previously too cumbersome to analyze. How does our forest productivity relate to soil characteristics? How does soil affect the flow of water through our watershed and into our lake? Where is the least destructive site for future development on the campus?

The job of locating data on maps has been made easier by the recent addition of a Global Positioning System (GPS) base station and remote unit, provided by Trimble Navigation. This system enables the team to accurately map features within a 300 kilometer radius of the school and has opened the door to collaborations with other groups in the area, such as local park systems and museums.

Once students become familiar with this spatial way of thinking, they are able to pursue other projects beyond the campus. Since most of the students taking this course are 10th graders, they can choose to do more advanced independent work for another two years. One student, for example, is learning to use the GPS technology with the goal of teaching others and then mapping the suitability of area streams for possible brook trout spawning. Other students will work with a local park system to develop a GIS.

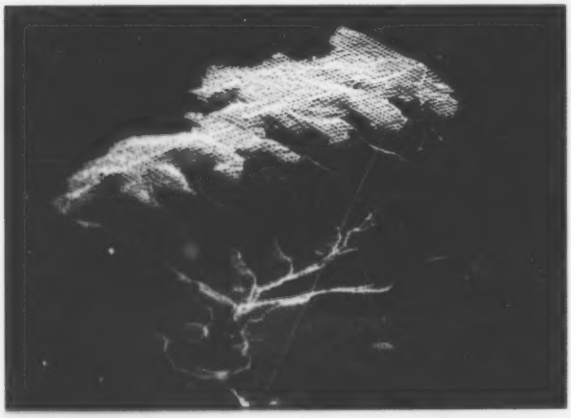
With the help of Barrett Rock of the University of New Hampshire (See "Kids, Satellites, and Ground Truth"), the school has joined the New Hampshire Space Grant Consortium's study of white pine and ozone and will expand that study into northern Ohio. This program will engage 7th and 8th graders from University School's Lower School campus in addition to our high school students. It will help to introduce these younger students to the importance of mapping, remote sensing, and GIS in scientific field work.

The lessons of such a collaborative, cross-disciplinary approach are numerous. Students become sensitive to the difficulty of collecting reliable data. The importance of scientific understanding as a basis for policymaking becomes obvious. The benefits of working effectively as a part of a team in order to deal with complexities that increasingly exceed the grasp of individuals become undeniable. Finally, it is hoped that students will see the need to pursue further study in traditional disciplines such as chemistry, physics, biology, geology, mathematics, statistics and economics.

During the past summer eighty 6th, 7th, and 8th graders from urban schools in the Cleveland area were introduced to the work described above in an enrichment program that uses the University School campus. The students were immersed in GIS-related activities for 4-6 hours daily for six weeks. A special attempt was made to relate the work being done in a suburban and rural setting to the urban setting from which these students come.

For the teacher, satisfaction in using GIS comes from many sources. In addition to traditional methods of evaluation, the student can be assessed on the basis of his willingness to attack real problems that do not always lend themselves to tidy solutions. The opportunity to observe and be observed by fellow teachers on a daily basis is invaluable. Above all, working in situations where unforeseen problems arise as a matter of course allows students and teachers to see each other in a new light. To the extent that teachers do not have ready-made solutions to these problems, students must share in the responsibility for team success or failure.

As teachers who came to this work with no previous experience in GIS, we have had a difficult road to travel. Our difficulty can be attributed to many sources. Our attempt to use GIS as a working tool has been hampered most by the time constraints of a traditional school day and the domination of a departmentalized, textbook-oriented traditional curriculum. This new approach does not lead to advanced placement testing and must constantly be defended against charges of soft science. Due to such perceptions, in a prep school like ours we have great difficulty attracting the best students. We believe that this problem needs to be addressed in the form of a dialogue that engages college admissions offices, high school college guidance professionals, and the GIS community at large. Professor Rock's work in New Hampshire seems a perfect start.



Students collected vegetation data in the field to develop a vegetation database for the 200 acre campus using ArcCade/ArcInfo software.

The tools for teaching GIS to pre-college students have been, until very recently, inadequate. When we first started our work, we found almost no material that was accessible to 10th graders. We also felt very isolated, with few people to talk to about the prospects of using GIS with high school students. We welcome the evolution of a network of support for pre-college educators that this conference promises to launch. The lack of necessary hardware and software in most schools is a problem that has not plagued us due to the generosity and vision of many individuals and organizations. However, it is a problem that must be addressed elsewhere at this conference.

Finally, we have been hampered by the lack of good data that would allow us to study our local surroundings. Satellite imagery of a local setting is still too expensive for schools to use effectively, and we find that we must make endless phone calls to find usable data. Despite these obstacles, we are more convinced than ever that GIS is a wonderful teaching tool. We believe that the type of local work we have attempted with GIS now needs to be placed within the context of regional networks of schools that use GIS to collaborate on larger scientific projects. The monarch butterfly study being done in Kansas by Steve Case and Brad Williamson (See "Monarch Butterfly Migration Student Investigations") and Professor Rock's work in New Hampshire offer good examples. Our goal for the near future is to help build such collaborative efforts in northern Ohio. We welcome any inquiries about our experiences.

Monarch Butterfly Migration Student Investigations

by Steve Case and Brad Williamson

Steve Case and Brad Williamson are science teachers in Olathe, Kansas. They have collaborated in establishing the Kansas Environmental Monitoring Network and in participating in the TERC Global Laboratory Project. During his years as a high school and middle school teacher, Steve Case's goal has been to engage students in the excitement of doing science. As a high school biology teacher, Brad Williamson has been deeply involved in grassroots efforts to empower teachers and students in collaborative research with scientists. Applying Geographic Information Systems to their work was a logical next step for Case and Williamson.

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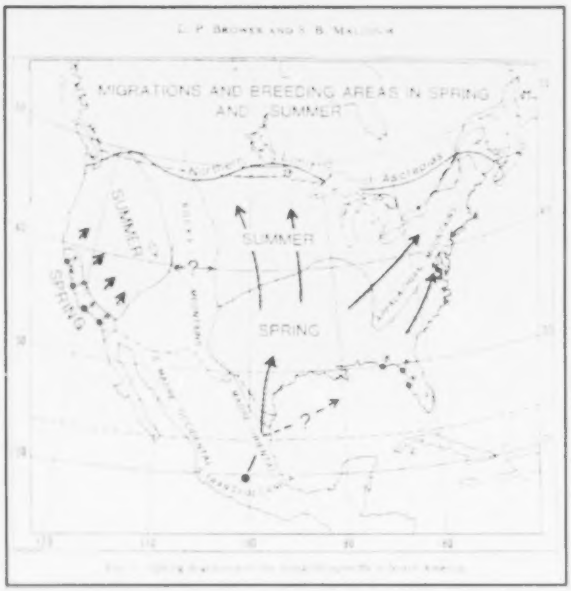
The education community is often in a quandary when it comes to making decisions regarding the applications of new technology. The rapid development of Geographic Information Systems and Global Positioning System technologies is creating just such a quandary. Should we simply utilize GIS for enhancing pedagogy or is GIS best used as the tool for which it is designed—to open new areas of inquiry and analysis of geographically based data? We argue for emphasizing the second application. We present here examples of student collaborative research projects modeled on the TERC Global Laboratory Project. Each of these projects involves the collection of spatially and temporally dispersed data over large geographical areas by networks of cooperating teachers, students, and researchers.

KEMNET is a grassroots network of teachers and students from across the state of Kansas dedicated to monitoring changes in the global environment. KEMNET is predicated on the premise that the best way for students to learn science is to do science. Whether or not students continue in science, they need to understand and appreciate its process. They need to understand how knowledge develops, and they benefit from understanding the thinking and problem-solving skills involved in research. The KEMNET model allows students to grow into the scientific process without initially experiencing the full creative burden of the project design. Researchers, who are well practiced in developing answerable questions, provide the necessary creative framework. As students participate in that research framework, they begin to generate their own questions.

KEMNET research projects such as the Monarch Butterfly Migration described below have demonstrated that students indeed can do science from the standpoint of data collection. The appropriate application of GIS to these data opens a new realm of doing science for students. Now, in addition to facilitating acquisition of data, GIS applications can provide sophisticated analysis and graphical presentation of data. This empowering technology allows students to develop insights never before possible.

Monarch Butterfly Migration Project



Courtesy of American Zoologist Magazine, Volume 31 (1991).

Many questions need to be resolved regarding the endangered monarch butterfly migration phenomenon. Some of these questions are best answered with a geographically dispersed network comprised of volunteer observers. Such a network exists in a project that involves hundreds of teachers and thousands of students working collaboratively with Dr. Orley Taylor at the University of Kansas.

The eastern monarch migrations are a North American phenomenon. The fall monarch migration proceeds in several waves at a pace of approximately 50 miles per day, unlike bird migrants that can be here today and gone tomorrow. For sites in Kansas the migration phenomenon can be observed for about four weeks. To study bird migration effectively, students would need to travel to specialized habitats such as wetlands or forests, but monarchs are not so specialized. They are slow daytime flyers which can be observed in nearly all school settings, including urban locations. Flight vectors are easy to observe.

Some of the ways that GIS can support the student research in this project are:

Mark and Recapture Tagging Studies—Using a network of volunteer participants, monarchs from five regions of the eastern U.S. are tagged with wing tags that are color-coded to region. With each region of the country represented by a distinctly colored tag, important migratory flight information can be determined.

Vanishing Flight Vector Analysis—Flight vectors change hourly throughout the day. Quantification of these variations over a wide geographical area provide important information regarding monarch navigation, as does analysis of vanishing flight vectors. It promises to be a fruitful field of research requiring extensive data collecting that is both spatially and temporally dispersed. These data are relatively easy to collect reliably and yield very rich information regarding migratory behavior.

Photobiology—Another area of proposed research is to examine the relationship between migratory flight vectors and photobiology. We will approach this problem over a full-year period with a group of schools culturing monarchs under both summer and fall day-night light regimes. These schools will then release the monarchs and record the ensuing flight vectors from the two different populations.

Temporary Roosts—Monarchs use a number of temporary roosts and nectaring sites along the migratory path. Cataloging and characterizing these sites will provide important information about the migration. Even though monarchs have been tagged for over thirty years by a number of researchers, little is known regarding these temporary roosts. GIS provides a particularly promising solution to the problems associated with trying to characterize the roosts.

Other Migration Issues—The monarch migration is a North American phenomenon, traversing three countries. Important baseline information needs to be collected regarding the migration so that

appropriate conservation actions can be initiated. We know very little about the migratory pathways in Texas and Mexico. Although the migratory pathway in the U.S. is changing with expanding urbanization, the effect of the urbanization has not been studied. The Mexican winter roost sites are threatened, and the timing of plant/monarch interactions has not been sufficiently characterized for either the fall or returning spring migrations. All of these questions require GIS.

In addition to the Monarch project, our students are involved with other investigations:

Cottonwood Leaf Stomatal Densities—This project is establishing baseline data of stomatal densities in the cottonwood tree, which has a wide distribution in Kansas and will respond to global climate change with changes in stomatal densities.

Kansas Department of Health and Environment's (KDHE) Stream Monitoring Program—Administered through KDHE, this program targets the monitoring of non-point source pollution in watersheds throughout the state.

UV-B Monitoring Efforts—In collaboration with TERC's Global Lab Project, Dr. Tom Manney at Kansas State University, and Forrest Mimms III, we are monitoring ultraviolet-B radiation levels. We are using specially designed meters to measure UV-B exposure. The biological effects are being studied using a particularly sensitive strain of yeast as a biodosimeter.

Like all technology, GIS is a tool for solving problems. It is an important tool that addresses problems in science education by making student collaborative research possible and meaningful.

Exploring Student Problem-Solving Strategies with GIS

by Richard Audet

Dr. Richard Audet is a Research Assistant Professor in Science Education at Boston University and serves as a Science Resource Specialist in the Boston University Partnership with the Chelsea, Massachusetts, Public Schools. His dissertation research investigated the problem solving styles of novice users of GIS.

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Some observers have linked the reform movement in education to advancements in technology and new insights about how people think and learn. Despite the knowledge that computers create unique problem-solving opportunities, surveys indicate that these tools are used mainly for drill, tutorials, and word processing. As awareness of Geographic Information Systems technology expanded, an informal network within the GIS community began to examine the potential of GIS as a technological tool for teaching about the world. Specific areas within existing high school curriculum where this technology could impact teaching and learning were examined. For example, Environmental Science students might custom-design a database so that significant, and real, local issues could become the target of student investigation.

Because technophiles focus initially on hardware and software issues, the expansion of educational technologies tends to outpace the associated knowledge base concerning learning and instruction. Compounding the problem is the common practice of making a priori assumptions about the potential benefits of educational technologies. Although many studies have explored the impact of computers on education, no previous work was found that investigated the educational applications of GIS in pre-college settings. Cognitive issues central to introducing GIS technology to high school students have been ignored. Curriculum materials generated before suppositions about the relationship between students, computers, GIS software, learning tasks, and instructional styles are tested may suffer fundamental flaws.

In 1993 a pilot study of the GIS program ArcView was conducted at the University of Wisconsin-Milwaukee. We observed that the seven high school students studied had little difficulty developing the necessary computer skills. However, evidence for effective application of problem-solving strategies in this computerized setting was meager. We were unable to account for differences in the degree of problem-solving success that individual students enjoyed with GIS. Would explicit problem-solving training affect learning outcomes with GIS? What were the differences between novice and expert users of GIS? Outcomes of the pilot program established a framework of a research agenda for investigating the complex cognitive relationship between teen-agers and GIS exploratory tools.

Methodology

The history of expert systems research is dominated by cognitive studies of problem solvers. Contrasting the activities of experts and novices within particular contextual domains helps to define cognitive criteria associated with "ideal" performance states. Our study investigated expert-based problem-solving behaviors with ArcView and an activity called the Novice Planner. For the purposes of this research, an expert was defined as any individual who possessed from one to five years of experience working with GIS software. Fifteen persons participated in the study (5 teachers, 5 high school students, and 5 GIS experts). Observations of each subject's problem-solving strategies were combined with scores on Problem Solving and Learning Style inventories and analysis of think-aloud transcripts and keystroke patterns to create Problem Solving Profiles for all participants. GIS problem-solving strategies expressed during reflective think-aloud sessions were evaluated through naturalistic research methods and analyzed for the presence of thematic components.

Results

Analysis of the keystroke command sequences revealed the existence of three distinct ArcView problem-solving typologies. These inclinations seem to be arranged along a continuum of strategic complexity from Trial and Error, to Spatial Querying, to Logical Querying. The trial and error approach consists of scrolling through a database until the solution appears. In GIS jargon, a "Spatial Query" involves the use of ArcView's tools or editing functions to control the View so that the answer to a question is displayed visually. ArcView permits the construction of Logical Expressions to question, or "query," the database by using specific search criteria. The unanimous preference shown by experts for the use of Logical Expressions to query the GIS database was judged to represent the most effective problem-solving approach.

Novices were more likely to

(a) focus on surface features of the problems

(b) use trial and error strategies

(c) be affected by personal interpretations of syntax and vocabulary

(d) act before shaping a full strategy

(e) continue to work without verification of accuracy

(f) change their ArcView style from problem to problem

(g) rely on spatial interpretations of information

(h) experiment with icons and tools.

GIS experts, in contrast, demonstrated a greater tendency to

(a) conceptualize a problem in terms of its essential, or "deep structure" characteristics

(b) make consistent use of Logical Expressions to query ArcView's database

(c) work with fewer procedural errors

(d) complete the problems quickly

(e) integrate ArcView into their existing conceptual schemata

(f) ask questions about their performance in terms of how it compared to that of their peers

(g) display end-directedness

(h) check for accuracy

(i) demonstrate concerns about the appearance of the View created during the problem.

Conclusions

GIS employs problem-based and project-oriented activities to create new, exciting, and authentic opportunities for students to learn about their world. By emphasizing local data, GIS makes studying the environment current, relevant, and meaningful to students. A feasible rationale for incorporating GIS into high school curricula rests on assumptions about its ability to enhance problem solving and decision making about authentic, real-world phenomena. Thus,

an essential question to be answered is whether applications of GIS support the development of problem-solving skills, and if skills taught in a GIS context can be successfully applied to other situations.

Specific types of learning experiences that move students toward demonstrations of expert behaviors must be elaborated. Other places in the curriculum where GIS might apply should be identified so that interdisciplinary connections can be formed. The link between cognition and GIS should continue to be studied. Naive conceptions and general misconceptions about mapping and spatial representations of data must be identified. The relationship of natural language to visual interpretations of information needs to be better understood. Implications of learning style and self-efficacy require further exploration.

The population of GIS users is undergoing a sweeping transformation. Future users are likely to include high school students working in high technology learning environments, or ordinary folk sitting in public access areas like libraries. Research into how people think and learn with GIS tools will help to develop materials, applications, and programs that are sensitive to the needs of non-traditional users. Until the educational research community contributes significantly to the ongoing dialogue, the risk is high that GIS may become another technology of enormous potential that failed to produce any lasting impact on education.

ESRI's Educational Initiatives

by Charlie Fitzpatrick

Charlie Fitzpatrick coordinates the K-12 Education and Libraries program for Environmental Systems Research Institute. For 15 years previous, he taught junior and senior high school geography in Minnesota. He continues to spend time teaching other teachers about geography and how to use technology in general, and GIS in particular.

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Environmental Systems Research Institute (ESRI) is a commercial producer of Geographic Information Systems software and is active in many aspects of the field of GIS. ESRI's software, such as ArcInfo and ArcView, is used in thousands of locations worldwide. ESRI is increasingly committed to promoting GIS in education.

From its beginning, ESRI has helped colleges and universities incorporate GIS in many departments. Mirroring the growth of GIS in the marketplace as a whole, a growing number of disciplines in higher education are using GIS: geography, geology, engineering, urban studies, environmental planning, forestry and agriculture, business and economics, political and social science, and ever outward.

Adopt-a-School Program

As GIS users in business, government, and research increased in number, and as the hardware and software for personal computers increased in sophistication, ESRI turned to the pre-collegiate realm as a natural audience for GIS. Sophisticated but friendly tools which permit exploration, analysis, and hypothesis testing across subject areas belong in classrooms at all grade levels. The "Adopt-a-School" program was inaugurated at ESRI's 1992 User Conference. From its start, the program has focused on promoting relationships between GIS users and their local schools. GIS users, in public and private sectors both, are encouraged to "adopt" one or more schools. Adoption involves sharing technical expertise, conceptual understanding, and non-proprietary data to help teachers and students learn to use the tool effectively. Along the way, schools may need additional assistance with acquiring and configuring hardware and software, and some schools may need a bigger boost than others. For its part, ESRI supports these efforts with a high-powered, low-cost bundle of software and data, site licensed to individual schools, and yielding detailed information at county, state, national, and global levels. By bringing local data to the scene, adopting users can complete the package and help immerse students, using data about the places that students know best. By participating in serious work with local schools, we hope these GIS users will also benefit by feeling even more engaged with their community than they might as neighbors, parents, and friends.

Geography Alliance Support

Since their genesis, state Geography Alliances (sponsored in large part by the National Geographic Society) have become powerful forces in the push for geographic literacy. Since the arrival of ArcView, ESRI has sought to assist Alliances in these efforts. By providing software and data to the headquarters of each Alliance, conducting demonstrations for summer institutes, and occasionally holding a full-day training event, ESRI has sought to help educate

the country's geography teachers. Many Alliance teachers have moved from demo to workshop to adoption and lobbying their school administration for upgraded hardware. The climb toward collective geographic literacy is a long one, but GIS is being viewed more and more as a vehicle for promoting the skills and concepts of geography.

Curriculum Support Materials

Even the best tools find it tough sledding when first moving into schools. Because new skills, concepts, attitudes, and technologies require special introduction, ESRI has developed a series of materials to promote the exploration of GIS, including:

"ArcView Explorer": a low-end PC-based tutorial about GIS and ArcView version 1

"ArcSchool Reader": a "now-and-then" newsletter with stories, basic technical information, printed instructions for using ArcView

"Explore Your World with a GIS": a series of integrated pieces being crafted, including poster, companion activity booklet, and data sets.

These and other items are designed to make the potentially intimidating appearance of GIS be more understandable and manageable for students and teachers with limited technical background.

Special projects

Many people involved with GIS and/or different facets of education have developed special projects for education using GIS. ESRI has sought to encourage and promote these efforts, frequently hooking up organizations with local schools, or users with the Geography Alliance in their states. Through its regional offices and the overseers of its national programs, ESRI has helped many community organizations and national networks build geographic data sets that would be of keen interest to the school community.

Public Libraries

At the same time as the Adopt-a-School program was beginning, ESRI increased its push for public access to GIS through libraries. Approximately 65 member libraries in the Association of Research Libraries have participated in a GIS Literacy Project for over two years. The goal is to facilitate access for the general public to what is (even if sometimes only by legal definition) "publicly available data." Information such as Census materials, perhaps physically locked in a closet or virtually locked within a maelstrom of charts and tables, can be made more accessible through electronic means and more understandable when explored graphically. Bringing the citizenry (young and old alike) into the library to explore important issues of a spatial nature is the goal of the organizations, the librarians, and ESRI alike. ESRI has once more expanded the opportunity demonstrated through this project by making available to any "public library" a high-powered, low-cost set of software and data, and by encouraging the GIS-using professionals to share important non-proprietary data.

The challenge to bring spatial literacy and data access to all citizens requires effort on many fronts and coordination among many people. The battle will be long, but, fortunately, quite exciting. ESRI is honored to be able to work with so many enthusiastic students, excited teachers and librarians, and dedicated GIS users in schools, organizations, and businesses across the land.

Information about ESRI's educational initiatives are available fromESRI/ArcView (see the section Resources for GIS in Education—GIS and other Mapping Software)

Kids, Satellites and Ground Truth

Dr. Barrett N. Rock is an Associate Professor of Natural Resources at the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. On leave from UNH during the academic year 1994-95, he is serving as the Senior Scientist and Assistant Director for Science at GLOBE (Global Learning and Observations to Benefit the Environment), an international environmental education program in Washington, D.C. His research is focused on assessing the impact of air pollutants on forest species, and he has developed several K-12 educational outreach programs in northern New England patterned after his own research activities.

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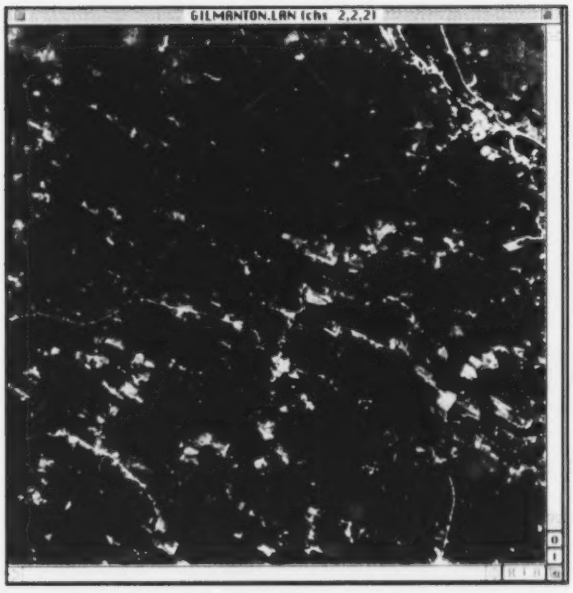
The University of New Hampshire has developed a region-wide Earth Day activity designed to introduce teachers and students to field, laboratory, and satellite data analysis methods for assessing the state-of-health of local white pine forest stands. This program, Earth Day: Forest Watch, provides workshops for grades K-12 teachers to train their students in the use of selected techniques for evaluating the health of white pine (Pinus strobus), a known bio-indicator for tropospheric ozone damage. Through the Forest Watch program, students become actively involved in doing real science, and in the process, contribute real data of use to UNH researchers conducting a regional survey of white pine in New England. Now in its fourth year, the program includes over 70 schools in New Hampshire and Maine. Seventy-four schools participated in 1993. Data from future Forest Watch collections will be compared with those from previous years.

Beginning in late April, students participate in three types of activities, each patterned after ones conducted by professional remote sensing scientists. The activities include: 1) forest stand assessment, 2) laboratory-based assessment of damage symptoms, and 3) image processing/data analysis of Landsat Thematic Mapper (TM) data for the area around the students' school. Each activity is designed to provide results that are both quantitative and meaningful at a range of scales, from the cellular level, forest stand level, to the regional level. These field and laboratory measurements are sent to the University of New Hampshire, where they are analyzed and integrated into the regional white pine study. Students also collect samples of white pine branches which are sent to UNH and analyzed with a field reflectance spectrometer. Each year a compilation of Forest Watch results is published, consisting of all student-generated field and laboratory measurements and the spectral reflectance measurements for the students samples.

Forest stand assessment activities introduce students to ground truth activities designed to provide data on forest stand parameters such as species composition, tree size for five permanently-tagged white pines, canopy closure, and ground cover, all for a ground area which represents a 30m Landsat TM pixel. Students lay out the pixel; select and tag five pines within the pixel; and estimate tree height using hand-made clinometers to determine the angular



Satellite image of the Gilmanton, New Hampshire, area.

distance to the top of each tree from a known baseline distance (multiplying the baseline by the decimal tangent value for the angle). They determine tree diameter at breast height (DBH) by measuring the circumference at 4.5 ft. above the ground and dividing by pi; use a hand-made canopy densiometer to determine percent canopy closure; and measure percent green ground cover. All these activities produce data useful in comparing each school's white pine pixel with all the other schools' white pine pixels within the Forest Watch study area.

The laboratory-based analysis of white pine foliage for ozone damage begins with the collection of duplicate sets of branch samples from each of the five permanently-tagged pine trees. One set is sent directly to UNH for spectral analysis, the other returned to the students' laboratory. The students identify each branch sample as white pine, using a dichotomous key, and select needles for further foliar analysis. Each student measures a total of ten current-year needles, recording needle length, percent occurrence of foliar symptoms (chlorotic mottle and tip necrosis) indicative of ozone damage, and number of years of needles retained. Healthy white pine may keep up to four years of needles but will shed older needles if they are not productive. The fewer the number of years of needles, the less healthy the tree. In some of the more heavily polluted areas of New England (along the sea coast, near big cities), only one or two years of needles are retained, based on last year's student data.

In addition to measuring needle length, amount of foliar ozone symptoms, and number of years of needle retention, students are introduced to hand-sectioning of needles (using razor blades) for study with microscopes. By sectioning both healthy and damaged portions of needles, students are able to investigate the cellular-level basis for the visual symptoms (chlorotic mottle, tip necrosis, etc.). Two optional activities, extraction of chlorophyll pigments for analysis with a Spec 20 laboratory spectrophotometer, and determination of wet weight/dry weight values for current year needles, are conducted by many of the older students (primarily in high school). Both the Spec 20 results and the percent canopy moisture data can be compared to the UNH spectral reflectance data for the duplicate branch samples.

The image processing and data analysis of local Landsat TM data allow the students to apply their ground truth data from the first activity to developing an interpretation of satellite data for their own backyard. The software used is MultiSpec, developed by Dr. David Landgrebe at Purdue University as a NASA-sponsored learning tool, for use with a Macintosh computer, to analyze Landsat TM, SPOT multispectral/panchromatic, and AVHRR satellite datasets. It is free of charge when used for educational purposes. Value-added TM data in 512 X 512 pixel sub-sets of local school areas are supplied through both the New Hampshire and Maine Space Grant programs. Students are encouraged to develop their own field trips to further ground truth their images.

Earth Day: Forest Watch combines space-age technology with old fashion biology to excite students and involve them in real science activities. Integrated field, laboratory, and image processing activities introduce students to the use of Earth-orbiting satellites as environmental monitoring tools. Although the present program focuses on white pine, similar programs assessing other sensitive bio-indicator species could be developed.

GeoSphere Project

by Tom Van Sant

Tom Van Sant is a sculptor, painter, muralist, architectural designer, and environmental planner. As Founder and President of the GeoSphere Project, he and a team of scientists and artists have focused on advanced scientific visualization, environmental research, and education. VanSant is perhaps most known for the GeoSphere Image, a widely distributed composite satellite image of a cloudless Earth.

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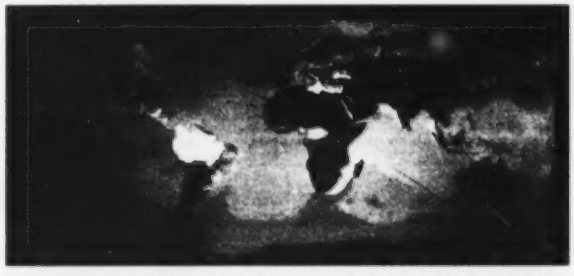
The goal of the GeoSphere Project is to create and distribute the world's most advanced global information display system. The GeoSphere Image, Global Visual Library™, GeoSphere Globes, and the Earth Situation Room™ network are products developed in the last five years by the GeoSphere Project for a wide range of applications. They are designed to serve world resource management, education, a universal library, business information systems, policy deliberation, scientific research, broadcasting, games, and print publishing.

The GeoSphere Project is based on global Geographic Information Systems. Geography, which has traditionally been associated with travelers and military commanders, has now emerged as a powerful means of information organization and display. A universal electronic library, based upon the location of information as opposed to where it falls in an alphabet, is now possible through advances in computing technology. Visualization of information in geographic terms, shown in animation through time, rendered in space, and layered to reveal relationships, may now deliver understanding of complex systems to users of all cultures and all levels of literacy.

Earth globes, large or small, are used in the home and in schools as reference instruments. Through technology, large globes may now become advanced delivery systems of the Global Visual Library. In addition, live feeds will monitor and display the issues of earth resource management, world weather, seismology, public policy, scientific research, global trade, human rights, and subjects of topical interest.

Phase One of the GeoSphere Project has produced the first high resolution (4 km), cloud-free satellite composite picture of the Earth as seen from space. Completed in 1990, this geosphere image is composed of 37.3 million digital picture elements (pixels). We are currently working on upgrading the 4 km image to a 1 km image.



"The Earth—From Space." Courtesy of the GeoSphere Project. Copyright 1990.

Phase Two of the GeoSphere Project saw the completion of the first 6 1/2 foot diameter GeoSphere "Reality" Globe in 1990. We are currently developing the projection of live weather patterns onto the reality globe by a direct feed from the three global weather satellites.

Phase Three of the GeoSphere Project consists of the integration and co-registration of the Earth systems global databases. These are being digitized, rendered for overlays, and indexed into a Global Visual Library.

Co-registration of the GeoSphere Image with World Topography Database and World Data Bank II has been completed.

Phase Four of the GeoSphere Project is the creation of the first Earth Situation Room, a world wide network of facilities that will receive, process, and disseminate visualizations of the Earth's global database information to education, media, publishing, and electronic forums.

The parent of the GeoSphere Project is Eyes on Earth, a nonprofit California corporation that licenses the GeoSphere Project to create and disseminate products generated from the research and development of Eyes on Earth. Products are published by GeoSphere Publishing Co., in book, globe, and electronic forms.

Satellite and Surface-based Observations of Atmospheric Aerosols

by Rudolph Husar

Dr. Rudolf Husar is Professor of Mechanical Engineering at Washington University in St. Louis and the Director of CAPITA (Center for Air Pollution Impact and Trend Analysis). His recent interests are focused on the development of a new discipline, environmental informatics, which is the application of information science, engineering, and technology to environmental problems.

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Atmospheric aerosols are the dispersing agents for man-made air pollutants, wind-blown dust, and biomass combustion products. Acid aerosols from anthropogenic sources are major contributors to acid rain, and they also have effects on human health. Within the atmosphere, aerosols cause visibility degradation and interference with electronic vision by satellites. A recurring major concern is the effect of aerosols on the climate through their direct and indirect perturbation of the radiative energy field and the possible retardation of the anticipated warming from greenhouse gases. At present, the spatial and temporal patterns of atmospheric aerosols over the continents are not well understood. Surface-based monitoring data are very sparse in space and time. Satellite-derived aerosol data are limited to cloud-free regions and to sensors in few wavelengths. A comprehensive global aerosol data set would allow the verification of aerosol-climate linkages and the investigation of the other aerosol influences. Student observations would fill major gaps in the current atmospheric aerosol picture.

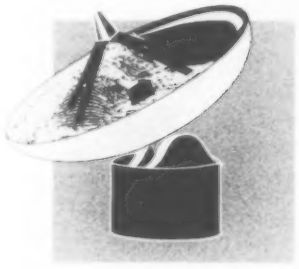
Student Project

The proposed project will combine atmospheric aerosol data detected by satellites with complementary surface-based measurements conducted by students. The satellite data will provide the broad spatial and temporal pattern, while the surface observations will provide the ground-truth data as well as augmentation over cloudy areas. The results will be daily maps of atmospheric aerosol pattern suitable for climate change and air pollution studies.The ground-based aerosol measurements will use a flexible array of measurement methods including human visual range observations, sun photometers, and filter samples. The daily observations will be transmitted to a central data processing unit where they will be combined with other data. The resulting integrated data set will be available online for analysis by the participants. The design of the measurement protocol, data flow, and continuous quality control will be supervised by active researchers, thus ensuring that the student-gathered data will satisfy the high quality requirements of scientific research. These participating scientists will also facilitate the incorporation of student data into global monitoring databases and assure the reverse flow of relevant data and scientific studies to the students.

Benefits

A strong scientific need exists for spatially and temporally resolved aerosol data from ground-based observations. Student observations will fill major gaps in the spatial-temporal aerosol pattern that is detectable by satellites. The proposed visibility and turbidity measurements are relatively simple to perform, inexpensive, and can be implemented in short time. The project is easily scalable by expanding the geographic coverage and time range of monitoring and by increasing the sophistication of monitoring methods. Involvement of students in a real-world project will sharpen their observational skills and advance their cognitive skills through collaborative data analysis, interpretation, and presentation.

GIS Software for Education



ESRI ArcView

by Charlie Fitzpatrick

Charlie Fitzpatrick coordinates the K-12 Education and Libraries program for Environmental Systems Research Institute. For 15 years previous, he taught junior and senior high school geography in Minnesota. He continues to spend time teaching other teachers about geography and how to use technology in general, and GIS in particular.

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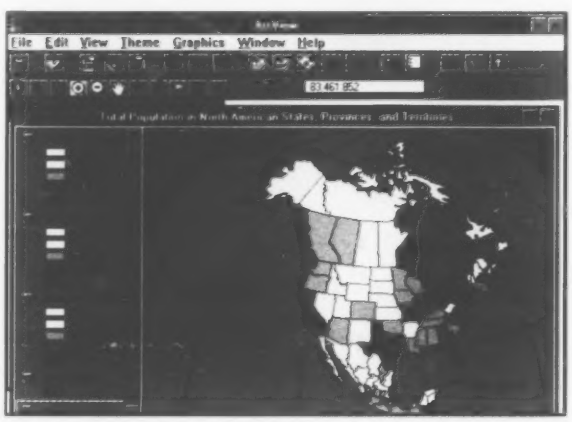
ArcView is "personal GIS software" that allows users to investigate information about places. It employs basic geographic data (information about where something is) in an electronic format and matches these data to other electronic information about what something is like. Different layers of data can be combined like transparencies on an overhead projector. The data sets can be tightly controlled or infinitely rich. One situation might include low-resolution boundaries plus three characteristics for 50 states; another situation might use high-resolution boundaries for multiple layers of geographic information, plus many characteristics about each layer, with the opportunity to add more data at will.

ArcView can be used effectively by people who are not GIS professionals, including teachers and students in pre-college classrooms and adults in public education arenas such as libraries and museums. With a mouse-driven, point-and-click interface akin to those found in current graphics or desktop publishing programs, ArcView users can explore the world in an intuitive fashion. Explorations may focus on any scale, global to local, depending on the data available. Volumes of high-quality, low-cost data are currently available for students and the adult community at large. With some basic skills, users can integrate their own data, import text and graphics, engage media clips from outside sources, and even customize the interface.

The heart of ArcView is exploration, satisfying curiosity of young and old alike and cultivating critical thinking in all situations. Users can explore the data available in many ways. Maps can be crafted and altered with just a few clicks, creating different patterns and exposing varied relationships. The data behind the maps can be examined in tables or displayed in charts, in a multitude of formats. With maps, tables, and charts linked dynamically, changes in one cause changes in the others, adding impact to the relationships. Users can modify the data, construct their own scenarios, pose "what if" questions, and present their findings in their own layouts.



Screen images are provided courtesy of Environmental Systems Research Institute, Inc. Copyright © 1994 Environmental Systems Research Institute, Inc.

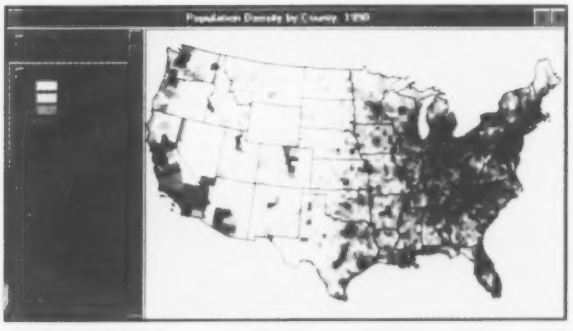
Where Does ArcView Fit in the Schools?

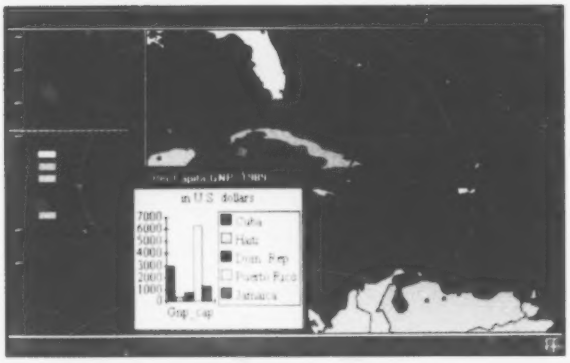
ArcView can fit into any grade level and any subject matter. The exact activities may vary widely from grade to grade and topic to topic, but the skills and principles endure. In each setting, exploration and discovery are key, with critical thinking skills fostered throughout.

In early grades, teachers with the help of ArcView can introduce students to maps as models and geography as a discipline. Important concepts of absolute and relative location, place, region, scale, symbolization, and generalization can be added. Students can begin to explore significant features of human and physical geography (e.g., mountains, cities, deltas, farmland) through satellite imagery. Or they can use relevant local area maps (e.g., neighborhoods, watersheds, forests), produced by local GIS users. Students should see that computers are tools with capacity for displaying information effectively and that maps are dynamic and representational displays (thus distortable) rather than static and "correct" portraits.

In middle school, students can begin examination of special topics and regions with ArcView, studying a given phenomenon over space to see how it relates to others. They can survey the characteristics and relationships of geographically varied traits (population, economic makeup, physical features). By examining a region and its features, students can begin to understand the complex traits that identify and unite or separate areas, at scales local to global.

With ArcView, high school students can expand the study of topics and regions and explore geography-related job markets. Earlier regional and topical





studies can be carried deeper or integrated with other studies. Students can focus on interrelationships between features and factors in other places. With the help of guidance counselors and teachers, students can survey occupations— urban planning, marketing, environmental engineering, energy and utility companies— that rely on ability to gather, process, analyze, and report spatially varied data.

In math classes, students can use ArcView to explore various map projections. They can investigate the process of locating objects with reference to relative and absolute markers. Or they can use the rich graphing and charting capacity to study the mathematical relationships between factors found at different places.

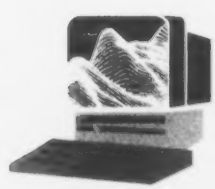
Science classes can expand analyses of environmental relationships by displaying in ArcView the micro and macro systems as they occur over space. Local environmental analyses can be enriched by seeking similar patterns in other places. Students can explore the impact on visible patterns by altering the electromagnetic radiation received in satellite imagery. They can overlay these images with ground mapping to examine how people and the environment influence each other.

In language arts classes, students can enrich reading exercises by exploring the nature of a place using ArcView maps. Conversely, mapping exercises can be supplemented by describing in writing the nature of a place or the analysis of relationships.

Social studies classes can practically live in ArcView, exploring decisions made in the past, and how those decisions were shaped by differences in characteristics from place to place. With data as fresh as the daily news, students can explore current events, conditions, issues, and conflicts, and see how their contributing factors are influenced by changes over space. All users can ponder the impact on societies caused by fundamental changes in technology and the types and amounts of information available.

With ArcView GIS, students and adults can learn how the many diverse facets of the world are integrated. They can learn the value of exploration, wondering, questioning. They can see a single set of information being portrayed in many ways. They can develop their analytical skills, exercise integrative thinking, and practice expressing their ideas effectively to others. And they can learn about the magical richness of the world and all that is in it. In short, ArcView GIS is a tool that promotes lifelong learning.

Information about ESRI's ArcView software is available from ESRI (see the section Resources for GIS in Education—GIS and other Mapping Software)



IDRISI

by John Auble and Michele Fulk

A graduate of Clark University in International Development, John Auble now directs the Program in GIS and International Devlopment at his alma mater. He teaches GIS courses and consults locally on GIS issues. His previous affiliations include the Peace Corps, Connecticut Sea Grant, and the Philadelphia Department of Agriculture.

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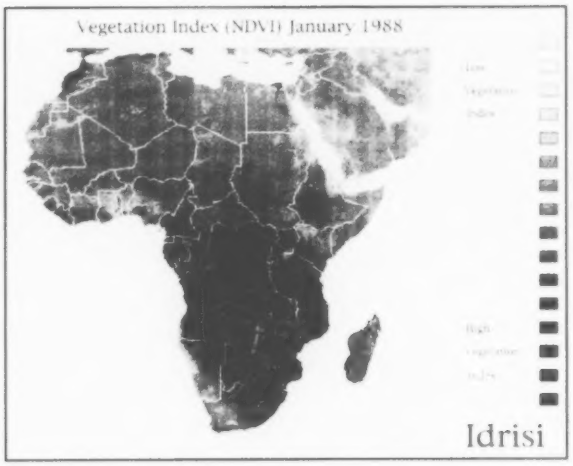
Since its first release in 1987, the IDRISI raster geographic analysis system has grown to over 11,000 registered users in more than 100 countries, making it the most widely used raster GIS in the world. Developed, supported, and distributed by the Clark Labs for Cartographic Technology and Geographic Analysis[1], IDRISI is easy to use, yet provides professional-level GIS, image processing, and spatial statistics capabilities on DOS-based personal computers. Selection of commands can be done either through a menu or by keyboard entry, with prompting for each input and default answers provided. A Windows version of IDRISI, with a complete point-and-click interface, will be available in spring 1995.

The data display module of IDRISI allows for a variety of interactive explorations. One option is cursor-controlled by the mouse. Information about the row, column, and geographic x,y positions, as well as the data value for any point, may be obtained by moving the cursor about the image and clicking on the mouse buttons. A cursor may also be activated for interactive zooming in and out of the image. The color palette may be interactively changed and customized and multiple vector data layers may be overlaid on the raster image. The user may also examine the data in a three-dimensional view.

In addition to data display, a full suite of geographic analysis and image processing tools are available to the IDRISI user. These range from basic GIS operations such as overlaying multiple map layers and reclassifying data values, to more advanced operations such as creating a landcover map from satellite imagery or calculating indices used by landscape ecologists.

A capability that may be helpful to teachers is the command line option. By using IDRISI command lines in a batch file, a series of operations that are too complex or time consuming for students to execute interactively may be performed with a single command issued from the keyboard.

[1] Affiliated with Clark University in Worcester, Massachusetts. In addition to software development, the Clark Labs are involved in the exploration of new analytical techniques, development of educational materials, training, and research in geographic analysis and information technology transfer and implementation.



Instructional Materials

The software is distributed with a set of tutorial exercises and data that guide the new user through the concepts of GIS and image processing while also introducing the features of IDRISI. The tutorial exercises are appropriate for use in self-study or in classroom settings. Though the intended level of this material is university undergraduate, the exercises have been used successfully by high school and middle school students. Similar materials, specifically designed for younger students, have been developed by other institutions. For example, the National Oceanic and Atmospheric Administration publishes a workbook for high school and middle school students to accompany its Global Change Africa Database. (See "Data Sources.")

The Clark Labs collaborated with UNITAR (United Nations Institute for Training and Research) to develop Explorations in Geographic Information Systems Technology, a series of workbooks. Each includes an overview that describes in detail the theoretical aspects of using GIS in a given application area and a set of exercises using real-world data to describes the issues raised. These materials are aimed at a university-level audience, but the exercises could be modified for younger users.

A magnet junior high school in Virginia is successfully employing possibly the most interesting and exciting use of IDRISI in the pre-college grades—the development of materials pertaining to students' local environments. Though database development can be a time-consuming process, it is a process in which students may participate and learn a great deal. Over the course of several semesters, an interesting database can be developed for the students' local area, and analytical questions can be posed that require students to use the database and the GIS to find the answers. This activity encourages an interdisciplinary view of the environment, as biological, physical, social, and even historical data layers are all integrated into the database.

Software and Hardware Systems

IDRISI is intended to be affordable to all levels of users. Accordingly, it is sold under a three-tier price structure, depending upon the type of user: commercial, academic/government/nonprofit, and full-time student. Site licenses are available. When determining the costs of maintaining a GIS lab in the long term, it is important to consider the costs of periodic updates, which usually occur once every one and a half years, and technical support, as well as the initial purchase.

Designed to run on the most basic of common computer platforms and successfully used on networks, IDRISI requires no expensive graphics cards or peripheral devices. To work with IDRISI, your system must be a PC-compatible, have 512k of base RAM available, VGA, SuperVGA or 8514/A graphics capabilities, a hard disk, and a Microsoft-compatible mouse. The recommended processor is a 486, but the software will run satisfactorily on a 286 if the data sets used are fairly small.

Information about IDRISI software is available from IDRISI (see the section Resources for GIS in Education—GIS and other Mapping Software)

GEOSCOPE: The Encyclopedia of Planetary Changes

by Luc Michaud

President of LMSOFT, Luc Michaud has a doctorate from the Universite de Montpellier and has participated in numerous environmental cost-benefit studies in areas such as acid rain, the Archipelago Project, recreational salmon fishing, and the Sainte Marguerite development and the willingness of people to pay for quality landscapes. For the last ten years LMSOFT has also developed software for education and for the general public, including GEO-PRO, a map generator, Economy Simulator, and GEOSCOPE.

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One of the most remarkable results of the conquest of space has been, paradoxically, a new awareness of the Earth itself. The first astronauts left with their eyes turned towards the immensity of outer space. Once they were well on the way, though, they turned back to where they had come from, and every one of them was struck by the beauty and fragility of this blue jewel, hanging in the midst of a hostile void. The photo taken by Apollo 11 has become a symbol of that new vision: the blue planet, humanity's spaceship. We now know that we will have to take care of it so it can continue to carry us safely.

Since that time, space and the environment have come together in another way: the observation of our planet using satellites. For the last twenty years, some ten satellites (not counting military satellites, the number and characteristics of which are secret) have been observing various phenomena and every day transmitting hundreds of gigabytes of raw data.

The appearance of Earth observation satellites and computers has had profound effects on the study of territory, so much so, in fact, that the term itself has been changed for the occasion. Geography has now become Earth Sciences, and employs a huge range of new concepts and tools, while conserving, and even expanding, its multidisciplinary nature.

GEOSCOPE is intended to be a means of helping students become familiar with satellite imagery and the vast amount of planetary data sent by satellites.

In 1986, twenty space agencies from across the world decided to mark the contributions of space technologies by creating International Space Year (1992). One of more than one hundred projects initiated that year, GEOSCOPE is intended to increase awareness of the new instruments of Earth Sciences among the general public, that is, all those who have

an interest in planet-wide changes. Canada has directed the project, under the auspices of the Canada Centre for Remote Sensing, in collaboration with the Canadian Space Agency, NASA and NOAA, and the Quebec Ministry of Education.

The mission of GEOSCOPE is to ensure that the new tools of Earth observation take their rightful place among the instruments used for the analysis and management of the environment. GEOSCOPE provides data to observe the planet and changes that sustain it, simplified instruments to analyze and understand phenomena, and tools to communicate the results. GEOSCOPE is intended to be a means of helping students become familiar with satellite imagery and planetary data, and a tool for professionals working in the field of Earth Sciences.

The Components of GEOSCOPE

A metaphor is used to stimulate the GEOSCOPE user by giving him or her a role, that of a scholar from the last century who has invented time travel. The scholar arrives in our era and is provided with an orbital station equipped with GEOSCOPE's data and tools. Using these, the scholar will learn about the changes that have occurred since his or her departure and the knowledge we have acquired about the Earth.

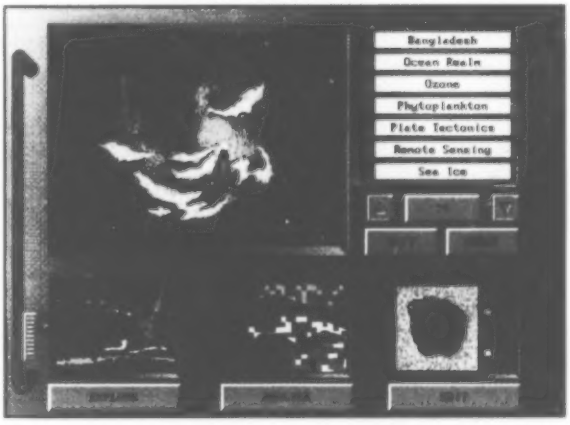
Scenarios

GEOSCOPE provides the tools to create and display multimedia scenarios, and several developed scenarios are included in the package. Produced using basic material provided by about forty scientists, the scenarios include 1,500 texts, original illustrations, photos, and animations. It takes about fifty hours to go through them all. The scenarios are very easy to use and permit anyone to be immediately at ease with the product. A glossary of 600 words and bookmarks help the user move through the information.

Database

The GEOSCOPE database includes a substantial amount of data on the whole planet, as well as much more that is specific to continents, countries, and even cities. For example, we find:

- images from ten Earth observation satellites, some from the time they were first sent into orbit
- thematic data on climates, ecosystems, vegetation, soils, geology, etc.
- socioeconomic data: 240 variables on 140 countries, on subjects such as demography; economics; trade; agriculture; wildlife, energy, water and fish resources; gas production; the greenhouse effect.



This control panel allows users to access GEOSCOPE's data and tools.

Each item of data is accompanied by a three-page document that explains its significance and provides information on its authors. In addition, all the data are in compatible projection systems and scales in order to facilitate comparisons, mathematical operations, and other manipulations.

For all those who are interested in geography and Earth Sciences, GEOSCOPE constitutes, for its database alone, an indispensable reference tool. But GEOSCOPE is much more than a simple collection of scenarios and images. It is also a software package that permits the manipulation and analysis of data according to personal research objectives.

Editing Images and Maps

To manipulate the satellite images, GEOSCOPE offers all the functions required to modify class boundaries and the color scale, according to the rules of the art of remote sensing. At the same time, it is so easy to learn and use that students can discover the operation of the functions through successive tries.

This mode includes zoom tool, a legend generator, and an X,Y tool to obtain the value of each point of the image. The camera tool permits you to store the image in your workplace, turn it into a .pcx file, or print it.

With images for which there is a series over time, such as ozone, temperatures, or the ocean, animations can be created directly.

The socioeconomic data are stored in a spreadsheet, from which you can choose variables to represent and set the class boundaries using a procedure similar to that for raster images.

For editing the vector data, zones can be created or modified; you can either digitize directly on the screen or import files in Digest format. Functions such as the automatic extraction of polygons greatly simplify the task for those with no previous training in geomatics, which is the great majority of us.

Variables and years can be added directly to the spreadsheet, which permits the personalization and updating of the socioeconomic data.

Analysis of Images

GEOSCOPE makes the field of image processing accessible to everyone, with simplified but precise functions that are excellent means of becoming familiar with these instruments and exploring the database in more detail.

The analysis functions are:

1. *Profile:* distribution of values along a line in an image;
2. *Histogram:* distribution by classes of one or more images;
3. *Scattergram:* diagram of dispersion between two images and least-squares line;
4. *Area:* measurement of a phenomenon (range of values) in an image;
5. *Statistics:* average and standard deviation of images;
6. *Arithmetic:* addition, subtraction, multiplication, and division of images (for example, to measure the difference in precipitation between two summers);
7. *Mosaic:* several images in tiles on a screen in order to view the differences;
8. *Mask:* create masks, for example, to exclude oceans from calculations on land above the surface;
9. *Scale:* ability to put data on the same scale before doing other calculations;
10. *Regrouping:* reduction of the number of classes of data by aggregating them;
11. *Overlay:* calculation of the intersection between two images and creation of new combined classes;
12. *Batch:* management of analysis operations, which can be very long, so that they are executed automatically during the night, weekends, and even during vacation!

These editing and analysis tools are the basic instruments for the management of the environment of our planet. GEOSCOPE permits you to discover them in an environment rich in concrete and varied examples. There are significant possibilities for use, in keeping with the potential of these new techniques of the Earth Sciences.

But GEOSCOPE is still more than a database and software tools: it is also a communication tool to permit you to share your results with others.

Hypermedia Authoring System

GEOSCOPE includes a true hypermedia authoring system. In addition to the fact that it is an integral part of the way the product functions, it includes two notable characteristics:

- The design of scenarios is simplified as much as possible: starting from a first image, you draw a rectangle, which is designated by the term "connection button" by clicking and dragging the mouse. As soon as you release it, a dialogue box appears in which you specify the appearance of the button, the text to be entered, and the type and the name of the file to be associated with that button. A click will take you to that file, where other buttons are available, and so on. GEOSCOPE's hypermedia system is distinguished by its ease of implementation for the design of scenarios.
- The system specializes in the field of Earth Sciences: the zones in the vector maps can be used as connection buttons. Thus, if text is associated with the zone Canada, it can be accessed by clicking anywhere inside the country, even in an island such as Baffin Island. In addition, the X,Y tool permits direct access to the database from any zone (country) on the map.

Once the scenario is completed, it can be saved in the workspace of its author. Even better, thanks to the functions of the file management module (to sort the workspaces, import and export raster and vector images, etc.) the scenario can be compressed on disk and then sent to a colleague or to other interested persons.

Already many users of GEOSCOPE have begun to produce scenarios, such as the one on El Nino prepared by the University of Southern California. Other organizations have used the GEOSCOPE technology to create an encyclopedia of biodiversity.

The Future of GEOSCOPE

The first version of GEOSCOPE is now available. Even though it is difficult to predict its success, there are a large number of users, with varied and complementary interests. Through its database and its software functions, GEOSCOPE is an essential reference work in the field of Earth Sciences.

In a field that is changing so quickly, it is imperative to innovate constantly, and new functions are being developed to permit the updating of data and the exchange of scenarios using the electronic information highways. Users will be able to contact directly the producers of data and their colleagues through the Internet.

Marshall MacLuhan's prediction is coming to fruition: the blue planet is being transformed into the global village in which everyone is involved and working together for the preservation of our quality of life.

Information about GEOSCOPE software is available from GEOSOPE (see the section Resources for GIS in Education—GIS and other Mapping Software)

GAIA Software

Suzanne Meyer is a landscape architect fascinated with earth imagery and the power it has to make students of all ages realize that people are but one of many biological communities on this planet. A graduate of Pennsylvania State University, she has held positions in several landscape areas: garden design, land development, environmental impact assessment, and satellite image analysis at the Island Institute. There she worked actively on the Maine Coast satellite data archives. She now runs Samara Mapping Project in Pittsburgh, PA, an earth image analysis consulting firm for environmental inventory and mapping.

by Suzanne Meyer

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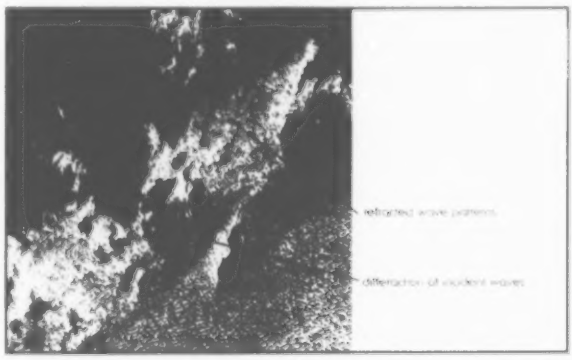
GAIA (Geographic Access and Information Analysis) software displays full scene satellite images on the Macintosh platform. Its intuitive interface and varied capabilities make it a valuable imaging analysis tool for desktop computers. GAIA software was designed at the Island Institute, a nonprofit organization based in Rockland, Maine, whose charge is to monitor the ecological and economic viability of Maine's 3,500 islands and coastal region. Satellite imagery has become a cornerstone in the Institute's landscape analysis of this large and sometimes remote geographic region. Our satellite data archives now cover much of the international, 69,000 square-mile Gulf of Maine watershed.

Using GAIA software to interpret, analyze, and create color thematic maps of satellite data is a streamlined and rewarding process. Currently GAIA is used by land planners, university-level biology classes, and environmental researchers. However, GAIA's strongest user base is in education, grades 3-12. In the 1994-95 school year, GAIA is installed in 92 classrooms in Maine. Its popularity is based on the ease of use of the software and ready access to remote sensing information.

In a classic use of GAIA software, third graders have used it to map out wetlands adjacent to a nuclear power plant in Wiscasset, Maine. Their concern was sparked by the intent to build a repository site for low-level nuclear wastes. These third graders and their teacher, Georgi Thompson, presented their findings at a town meeting about the site. The class's wetland findings were confirmed by the following speaker, a professional hydrogeologist. Using satellite imaging techniques through GAIA software, other students are mapping vernal pools for the Audubon Society; mapping water quality monitoring sites within a watershed; and conducting analyses of land use patterns that lie on top of sole source aquifers.



A Satellite view of wave patterns along the Maine coastline from Island Institute's SPOT Cutler image.

GAIA capabilities allow the user to display a full scene SPOT, Landsat TM, or MSS data sets. Processing the raw satellite data reduces the light reflectance values of the earth's surface from literally millions down to 60 colors or "classes." Within these classes, we can readily distinguish — on the Maine coast — 15 to 20 different land cover types, i.e., open water, shallow water, intertidal zones, rock and ledge, agriculture, shrub fields, maritime spruce, softwoods, hardwoods, mixed woods, development, and various wetlands. Of its many capabilities, GAIA allows the user to readily *zoom* into a single pixel from an entire data set, use a *crosshair* tool to display the pixel's numeric value, and then using the *blink* tool, flash that pixel value wherever it occurs over the entire image. This shows the user large-scale patterns, such as where a plant species, field, or development is occurring, by isolating a particular reflectance value and then viewing it on the whole image. It is in this way that users become familiar with the myriad of intricate relationships occurring within any landscape.

Users can further interpret the landscape on the computer screen by isolating and looking at any one of the spectral bands that make up the satellite data set. In SPOT satellite data, the green band yields information about intact or fragmented vegetative mosaics; the near-infrared band is useful in detecting dry vs. wet areas; and near-IR is used when determining hydrologic patterns within a landscape. Landsat data yield similar information.

As users continue interpreting the satellite image, they can group the 60 different light reflectance classes into subgroups, sharing a user-specified color on the screen. For example, 5 pixels (or light reflectance values) make up the oak community on a nearby hill. By putting those five values into an "Oak" group, one can then color that group to stand apart from the rest of the satellite image. It is this art of the GAIA/Macintosh interface that makes for a graceful and easy-to-use map-making tool.

Acreage tallies are another feature of GAIA that are an important component of landscape analysis. Suppose the user wants to know the extent of intertidal areas around his or her island community. The user would find those pixels that correctly identify the intertidal zone, group them into a "class," color that class, and then have easy access to an *acreage tally* that indicates how many acres the intertidal pixels comprise, as well as what percent of the total data set the intertidal zone covers.

The best part of using GAIA in an educational setting is taking students out in the field, having them pace off a 20-meter pixel (the smallest unit that a satellite sees in SPOT), identify plant communities and where they are occurring in a landscape, and how, if at all, they relate to one another. Back in the classroom the students can then find that area on the satellite image, group the "classes" that it contains, and find similar communities in the rest of the image. This introduces the students to the important aspect of "field truthing" an image (verifying satellite data on the ground), which they find extremely gratifying as it adds integrity to their data.

It has been great for us to watch the excitement, interest, and curiosity that sparks students and teachers who are using GAIA; we know from experience that it has been a fun and challenging learning adventure. In many of the schools, there are after-school GAIA clubs. One teacher takes interested students "field truthing" by going mountain biking to nearby sites on sunny weekends. Learning, at its best, is an integrative process. Learning to look at the world and landscape around us with fresh eyes, curiosity, and some new understanding is one of the benefits of working with satellite imaging. GAIA helps us do that.

Information about GAIA software is available from Island Institute (see the section Resources for GIS in Education — GIS and other Mapping Software)

Alice Network Software

Dr. Alan Feldman is the Project Director and co-Principal Investigator of the Testbed for Telecollaboration and co- Director of the Tools for Learning Center at TERC. His work focuses on the use of telecommunications to enable teachers and students to do project-based collaborative learning; his broad interests are in science education and the application of technology to learning. Before coming to TERC, he worked in schools for 18 years, as teacher and principal.

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The Alice Network Software has been designed by TERC, with support from the National Science Foundation, as part of the Testbed for Telecollaboration. The goal of the Testbed is to test a model of curriculum for collaborative inquiry among classrooms which share a common network. We have named this model "Network Science."

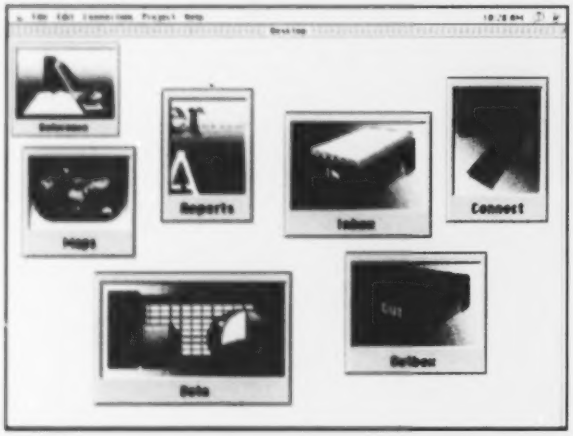

Figure 1

The Alice Network Software (Figure 1) is an integrated suite of tools (word processor, data table, graphing, mapping, telecommunications) that is easy to use and gives schools dial-up access through a host computer to the Internet. It was designed to address the most common situation in schools today: teachers with little software experience, no technical support available, and bandwidth limited to a modem connection via telephone line. Distributed widely to educators, the software is currently being used in hundreds of classrooms in this country and abroad.

In addition to the Alice Network Software, TERC has designed and built server software for data consolidation that makes it possible for large numbers of classes participating in a project to share data without tedious copy-and-paste operations. TERC has also done initial work to automate the role of the network manager for each project. These efforts reflect a priority in the Testbed for Telecollaboration of scaling upward to serve the needs of large numbers of students and teachers.

Mapping Tool

One of the design principles on which the Alice Network Software is based is that of multiple representations: students are more likely to make sense of data when they have some measure of control over how the data are represented. The software allows for many kinds of presentation—in the data table, in graphs, and as map overlays. In each case, students are able to exercise significant control over the representation. With data tables, they can sort, create subsets according to their own criteria, and look at statistics for each column. With graphs, they can choose among multiple graph types, graph the full data set or a subset, and change the ranges on each axis. With the map, data are displayed as an overlay

on a base map. The base map of the world that is presently available can be scrolled and zoomed at nine different levels. Data from the data table that has latitude and longitude associated with it can be mapped pointwise onto the map. The data can be represented in three different ways:

- actual values
- pie-shaped icons representing relative values
- groupings of values represented by colored shapes or colored letters

Students can change the kind of data representation, the grouping of values, and the scale of the map using a simple and direct interface.

In classrooms the mapping tool is used in different ways. Initially, students use the map tool to learn where their partner classes are located. Typically classes work in groups of 4 to 10 classes. Are our partner classes all in the same state? All located in the United States? All in the northern hemisphere? Geographic, cultural, and climatic differences are of great interest to students, so the map gives students information that is useful in stimulating dialog and developing a sense of a community. Classes can use the map to display information that they and their partner classes have collected. They can then look for patterns in the data. Are high values clustered together, as you might expect in a map of air pollution? Are certain characteristics of the data grouped near specific geographic features, such as sandy soil near bodies of water?

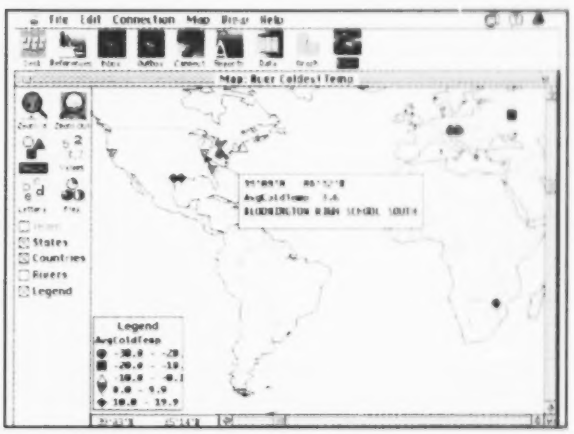

Figure 2. Temperature Data Submitted by Global Lab Classrooms

Figure 2 depicts a map of data submitted by 13 Global Lab[1] classrooms during the 1993-94 school year. These data were researched by students and submitted as the "Average coldest temperature over the past 10 (or more) years" in the city or town where the school is located. Five different shapes (which appear in color on color monitors and when printed by color printers) represent groupings of the data, ten degrees per grouping. Students can change the groupings to a wider or narrower band. By clicking on any data point, students can obtain the precise data represented by the point as well as additional information; this map was configured to show the name of the school.

The map enables students to see patterns in temperature data. Of this data set, the highest (warmest) of this set of extreme cold temperatures is in Texas. The coldest, -27.8 C, was reported by a school located in the southwest corner of Pennsylvania; temperatures almost as cold were reported by schools in the Czech Republic. It was surprising to see that the school in Moscow reported an average coldest temperature of -12.0 C. Based on the map, it is worth asking if the students in Moscow interpreted the category the same as the students in other countries.

The very simplest of tools in the GIS category, the mapping tool in the Alice Network Software is an excellent introduction for students to use in looking for patterns of variation in geographically based information. Equally important, it promotes use of student-collected data in GIS.

Future Directions

We are developing the Alice Network Software in several directions. Currently the map has a resolution of one degree of latitude or longitude in viewing a single base map of the world. In response to user requests, we would like to add the capability to plot data on maps of more localized areas such as cities or drawings of neighborhoods, school yards, rivers, harbors, or experimental study sites.

[1] In TERC's Global Laboratory project students conduct environmental investigations in their local areas, telecollaborating with their peers worldwide.

We are also planning changes in telecommunications. In the short term, the current version of the software (2.0), which presently does all telecommunications through a modem-telephone link to a specially-configured Unix Internet host (e.g., EcoNet and a host machine at TERC), will be enhanced to use Internet connections (SLIP, PPP, IP) in lieu of telephone lines. This will make use of Alice much simpler and less expensive for schools with Internet connections. In the long term, we are planning a substantially different version that makes use of the standards being established for the World Wide Web. This approach will make data consolidation and turnaround much simpler and more immediate. Students at hundreds of locations will be able to have greater interaction with a central database. They will be able to contribute data; view the data as tables, graphs, and maps; look at subsets of the data; and download the full data set or any part of it. Though classes with full Internet connections will have the greatest flexibility, classes which have only e-mail will be able to do many of the same functions, if somewhat slower.

Testbed for Telecollaboration

The Testbed has resources for assisting projects in initiating, establishing, and running Network Science curricula. The most recent information on the Testbed is electronically posted at TERC (accessible via Mosaic, http://hub.terc.edu/terc/alice). Key project documents (software, research papers, Network Science Handbook, and other descriptive materials) can also be retrieved via gopher and FTP as well as mail.

The Testbed for Telecollaboration is looking for a range of projects to work with, including:

- large national projects involving hundreds or thousands of classrooms, often using a published curriculum
- mid-sized projects, organized by a funded group such as a nature center
- small projects, initiated by one or more teachers and organized around a very specific topic or question

At the present time, the Testbed can only serve projects and not individual teachers looking to join a project. We expect to provide a service, in the future, for teachers to log onto a database to find projects or other teachers with similar interests.

Testbed staff are available to support projects in a variety of ways, from help in organizing a project to assistance in the design of data turnaround. However, the Testbed for Telecollaboration has limited funding to assist with these tasks, and projects with funding are expected to defray costs. The Alice Network Software is presently distributed at no charge.

Information about Alice Network software is available from TERC (see the section Resources for GIS in Education—GIS and other Mapping Software).

Accu-Weather Forecaster

Daniel Barstow, of TERC, was the Project Director for the EdGIS Conference and Editor of the Conference Report. He is also Project Director for the NSF-funded Kids Network curriculum project. Previously he was a teacher and Coordinator of Gifted and Talented Programs in the Hartford Public Schools, Assistant Director of the Talcott Mountain Science Center, and President of Metacomet Software, as well as author of the Accu-Weather Forecaster software package. His current focus is on helping teachers and students do real-world investigations using GIS and remote sensing, especially in urban schools.

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Accu-Weather Forecaster is a software tool that enables students to access live weather data, satellite photos, radar scans, and other current weather information. Using the powerful mapping and data analysis tools, students learn about the weather, understand current conditions, and make their own forecasts.

My focus in this article is on the development of thinking skills that the software fosters, rather than on its mapping capabilities, the key concepts of weather and meteorology that students learn, or the students' experience with telecommunications to access weather data worldwide within minutes of the actual observations. When I use Accu-Weather Forecaster with students, my goal is to help them develop and apply thinking skills such as data analysis, visualization, systems integration, problem solving, evaluation, comparing/contrasting, and, of course, forecasting.

A Typical Class

I would like to walk you through a typical introductory class with middle school students, first to have you experience the same process the students use, and then to demonstrate the type of thinking involved. Assume that we are in a computer lab and that the current weather data have already been downloaded. (A similar approach can be used with a one-computer classroom, or even without a computer at all, if there is a source of current weather data and maps, such as the Weather Channel or other TV forecast.)

Before the students touch the computers, we go outside to experience the current local weather. We estimate current temperature, cloud cover, wind speed and direction, and type and amount of precipitation. Based on this observation, the students make an initial forecast for the rest of the day.

Then we go inside and start filling out a weather observation and forecast form. On one side is a map of the U.S. (more on that later). The other side is divided into three parts: Current weather, Forecast for later today, Forecast for tomorrow. The students complete the section on current conditions (based on their personal observations), and make their best guess for the forecasts for later in the day and the next day.

On the other side of the forecast form, they start to record information on the blank weather map. They find our current location (in this case Boston,

Massachusetts), and record at that location the following information: temperature, cloud cover (drawn in, as in the example), and precipitation (also drawn in). Other data could be recorded, but we want to keep a simple focus during this first session.

Now it's time to use Accu-Weather Forecaster. I briefly explain to the students that there are several hundred weather stations in the U.S. (and many more worldwide) which take precise hourly weather observations. The observations are sent by telecommunications to the National Weather Service's central computer, which makes these data available to a number of public and private organizations, including Accu-Weather, Inc., the nation's largest private weather service. (You have probably seen Accu-Weather's forecasts on TV or heard them on the radio.)

Shortly before this class I had the Accu-Weather Forecaster software call up the Accu-Weather company's computer, download a pre-determined set of national weather observations, and then disconnect. So the current weather data are now on all the computers in the class, and we no longer need to be connected to Accu-Weather's computer. Let's find out what the weather is like throughout the U.S.

We begin with Boston, which is our nearest reporting station in this example. The weather data for Boston are depicted in visual form, as if you were looking out a window—with clouds, precipitation, a windvane and gauges showing temperature, dewpoint, and barometric pressure. (Figure 1). The students compare and contrast the National Weather Service's Boston report with their own local observations. If there are any significant differences, I ask them to speculate why this might be and to decide which report more accurately represents the current local conditions. If necessary, they make corrections to the local data recorded on their map.

Next, the students use the "Select Station" feature to select another location, such as New York City. A similar picture view appears. They consider the conditions in New York—in what ways they are similar or different from Boston— and record the three readings (temperature, cloud amount, and precipitation) on their map, at the location of New York.

This process continues until the students have recorded reports from roughly 15 locations throughout the U.S., trying to get a broad geographical spread. The students are, incidentally, learning a good deal of geography in the process. Eventually, they have enough data on the map to look for patterns.

Once the students begin to identify the patterns they see, the teacher must be prepared for the activity to branch in several possible directions, based on the actual data. Frankly, I like this aspect as it keeps the weather analysis fresh each time. Based on the current conditions, we might talk about regions of precipitation, or areas of snow versus areas of rain. We might look at cloud cover patterns and compare these with precipitation. Most importantly, the students are starting to make sense of the diverse weather reports.

To proceed with the next feature of Accu-Weather Forecaster— the automatic plotting of data on maps— the students display a national map showing temperatures from 100 stations throughout the U.S. I ask the class to find the warmest location, the coldest location, and any other patterns or anomalies in the raw data.

To help students visualize the patterns, I introduce the concept of contours and ask them to find all the values that are, for example, in the 40s. Similar temperatures usually appear as a wavy band stretching from the West coast to the East coast. With younger

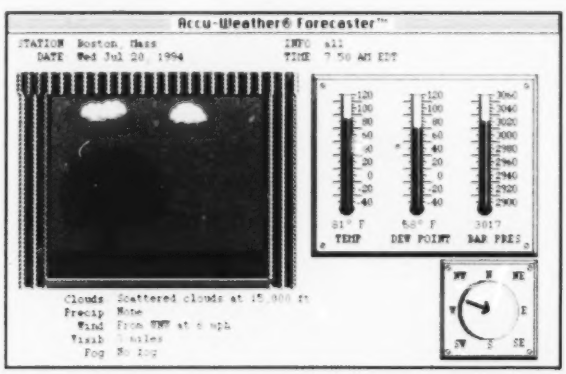

Figure 1. "Picture view" of the current weather in Boston.

students, I might print out this temperature map and have them draw a blue circle around all sites that have temperatures in the 40s (and other colors for other temperature ranges). Then I explain that the computer can help us by automatically drawing in the contours on the map. (The software is very easy to use. When contour maps are selected from a pull-down menu, the software automatically adds contours using a reasonable range of values for the bands.)

This stage usually elicits a few "ah-hahs," as students suddenly are getting a systemic view (see Figure 2). They now can see that the Northwest is

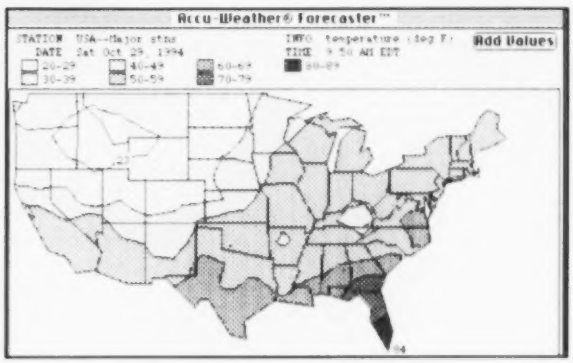

Figure 2. Contour Map showing temperature bands.

colder, or that a wave pattern becomes abundantly evident. After some discussion, students start adding information to their paper maps. For example, if there is a generally colder area (a cold mass) in the Northwest, they write COLD on that part of the map. Similarly they record WARM areas. Depending on weather conditions, and on levels of student understanding, I might also start to introduce the concept of the boundary line (front) between cold and warm areas.

Now it is time for the students to start refining their forecasts. With a warning that the following is a gross oversimplification, I explain that weather typically goes from west to east, generally taking three or four days for weather to travel across the country. Real meteorologists, and confirmed weather buffs, will certainly cringe at this concept, since steering winds, the jet stream, the patterns of the fronts, blocking highs, and the natural development patterns of storms often are more important than the simplistic west-to-east notion. However, my goal in this first session is to give students a starting point— to help them begin to understand that forecasts are based, in part, on an analysis of typical weather patterns.

I explain that one technique for making a forecast is to look at the weather to our west. If the weather a few hundred miles to our west is noticeably different (such as rainy or colder), then it is likely that weather will move east and reach us later today or tomorrow. Therefore, based on the temperature contour map, and the concept that the weather for later today is a few hundred miles to our west, and tomorrow's weather is a little further west, I ask them to modify their temperature forecasts on their forecast chart.

Next we proceed to cloud cover. Displaying the satellite photo of the U.S., I explain that this is a remote-sensed image from a satellite orbiting earth (see Figure 3). The students are usually pretty amazed that they have on their computers a photograph of the Earth taken by a satellite less than an hour ago. Looking at the image, they find areas of generally cloudy and generally clear skies and see that the satellite image, in comparison with their manually recorded data, adds considerable detail and complexity to the nation's weather picture. Again, with the (oversimplified) concept of weather moving west to east, they are able to add more specificity to the cloud component of their forecast.

Finally, students look at the national radar image, a composite of precipitation reports from a network of surface radar devices, showing precipitation type and intensity. They now add precipitation information to their forecasts and are able to start seeing the correlation, for example, among precipitation, cloud cover, and fronts. Their forecasts are complete.

At this point I caution that forecasts are probabilistic — a storm's motion depends on the complex interaction of many factors. Steering winds in the upper atmosphere may shift the storm's motion in a more southerly or northerly direction, or a stationary high pressure area may keep it from moving much at all. As I jokingly explain, "Weather

forecasters usually know what the weather will be, they just don't always know when or where." After one final review, the students are finished until the next day, when a new set of data will confirm the accuracy of their analysis and forecast, and provide the basis for moving on to the next day's forecast.

What Students Learn

Over time, students gain a deeper understanding of weather, based on a daily analysis of the weather, linked with lessons on key aspects of climatology, weather analysis, and forecasting. Just as with professional meteorologists, the more they learn and the more they practice, the better they are able to understand and forecast the weather.

Equally important, students experience a complex science with sufficient depth to appreciate the realities of both the content and the process. While this approach may take more time than is typically designated for "weather" in a science curriculum, I believe that it is an especially powerful, accessible, and engaging domain for experiencing real science.

Figure 3. Satellite view of Earth.

And as I have indicated, students are developing vitally important thinking skills. Reflect for a moment on all of the thinking that the students did in this lesson: observation, analysis, synthesis, comparing and contrasting, systemic thinking, visualization, forecasting, evaluation, and communication. The reality is that development of these thinking skills not only is essential for the students' future studies and careers, it is also, in my experience, the most effective context for students to learn the meteorological content of the class. The deeper you think about something, the more you remember it.

Information about Accu-Weather Forecaster software is available from Accu-Weather (see the section Resources for GIS in Education—GIS and other Mapping Software).

National Geographic Kids Network

Monica Bradsher has been developing science and geography materials for the Educational Media Division of the National Geographic Society since 1980, following ten years as a classroom teacher in Massachusetts, Virginia, Washington, DC., and Hong Kong. As one of the founders of the NGS Kids Network, she has advocated development of easy-to-use GIS software for teaching geography in secondary schools. She graduated from Swarthmore College and holds a M.Ed. from Harvard.

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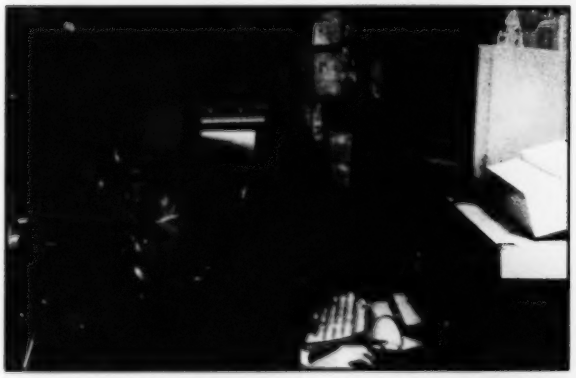
The advent of the National Geographic Kids Network software in 1988 may go down in history as the introduction of GIS basics to elementary school students. TERC originally developed this software for the Apple IIGS. But even within that rather primitive computing environment (no hard drive!) TERC was able to provide dynamic outline maps that give direct readouts of latitude and longitude in degrees and minutes and allow students to zoom from a world view to a view within a state in the USA.



During each NGS Kids Network unit, students collect data which they send to their teammates in the form of charts and letters. They use the computer and a modem to telecommuncate with students across the country and around the world. Richard Nowitz, National Geographic Society.

For typical elementary school students and teachers, Kids Network provides the first opportunity to manipulate map data on a computer. Students are excited when they see their own location highlighted on the map with the data they sent to the Kids Network. They check to see whether their data and the data of their teammates make sense and appear in the appropriate locations. They look for unusual data patterns and immediately want to investigate the possible causes. The students' work with the map data makes their study of geography come alive.

What Is Kids Network?

National Geographic Kids Network is a series of 8-week hands-on science and geography curriculum units designed for students in grades 4 to 6. Classes use computers and telecommunications to investigate significant questions and to exchange data with other students around the world. Schools in more than 40 countries have participated in Kids Network. Students in more than 15,000 classes were on-line in the 1993-94 school year.

By conducting research on real-world issues—acid rain, water quality, weather, solar energy, trash, nutrition—students become scientists and geographers. These Student-Scientists, as they are

addressed on the Network, make predictions, collect data, analyze their data, draw conclusions, and present their findings—all in a spirit of discovery.

Solid Curriculum Makes the Difference

One of the most important reasons for Kids Network's success is its well-thought-out curriculum units. Computer tools will not be used in classrooms unless teachers can see how the tools will help them teach what they are already expected to teach. Kids Network supports teachers in meeting requirements of their own curriculum.

The Kids Network curriculum makes the basics seem relevant to students. The inquiry-based activities help build skills such as understanding latitude and longitude, knowing geography place names, and noticing similarities and differences in cultures. Teachers often say they had been teaching latitude and longitude for years but were unable to show students how this information was immediately useful until they took part in Kids Network. Student-Scientists are motivated to learn such concepts quickly because they are anxious to know more about distant schools and to communicate with them.

Kids Network accommodates students with different learning styles because they can participate in hands-on activities that involve multiple modalities. In their small discussion groups, students can approach a problem from a variety of angles, and in such a context, using a computer to view data in different representations becomes helpful and fascinating.

Kids Network II Is Coming!

The collaboration between the National Geographic Society and TERC continues. The next series of Kids Network units for grades 6 to 9 will help students and teachers begin to work with more advanced mapping and graphing tools. Instead of waiting for National Geographic to compile data and send map files, classes using the new curriculum units will be able to make their own data files and display them as maps. Because these units use the Alice Network Software, students will be able to experiment with more graphing formats than in the units for elementary grades (see "Alice Network Software").

Four Kids Network II units are nearing completion, focusing on soil, human physiology, sound, and water. These units are designed for students who are ready for more content and depth of inquiry than the earlier Kids Network units contain. For example, participants in the new unit "What Is Our Soil Good For?" will conduct collaborative research into many intriguing questions: How do our lives depend on various properties of soil? Is our local soil being used wisely? What can we do to prevent destruction of this ecologically vital resource? Students will examine data in tables, maps, and graphs to help uncover answers to their questions.

Also, Kids Network II will contain time-saving tools for "authentic assessment" with guidance in evaluating student learning; extensions into other disciplines for integration and coordination in team-teaching situations; and alignment with the emerging national standards in science, math, geography, and English as well as with thematic curriculum frameworks.

As Kids Network moves into higher grade levels and offers more software capabilities, teachers will become interested in trying to use true GIS systems with their students, and students will be better prepared to meet the demands of the modern workplace.

Information about Kids Network software is available from National Geographic Society (see the section Resources for GIS in Education—GIS and other Mapping Software)

EOSAT—
Remote Sensing and GIS

Anthony R. Shupin is Manager for Marketing and Sales, as well as Academic Programs Manager, for EOSAT's Eastern United States and Canadian Region and directs, develops, and coordinates new application strategies for Landsat data and other forms of remotely sensed data. Under his direction, joint efforts to develop curricula and educational support programs have occurred between EOSAT and several organizations including the National Council For Geographic Education, National Center for Geographic Information and Analysis; Jason Project, WGBH-TV, and GAIA Crossroads Project.

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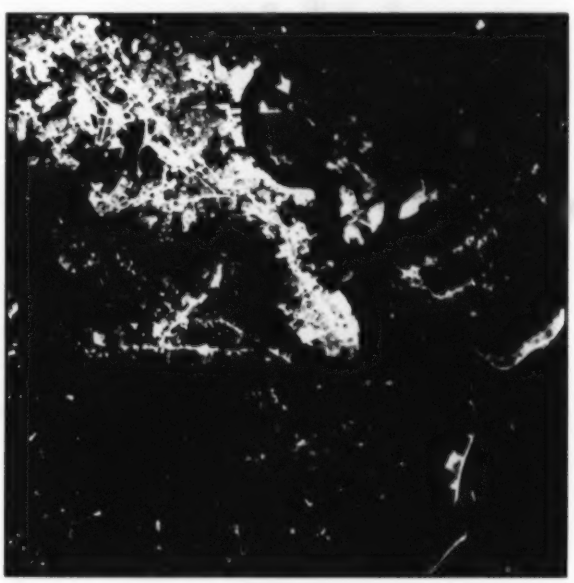
"Observation more than books,experience rather than persons, are the prime educators," noted Amos Bronson Alcott, a 19th century educator and philosopher generally acknowledged to be far ahead of his time in his thinking about education. However, many of his ideas have become mainstream in current society. Today I would like to discuss and illustrate how remote sensing imagery can promote the kind of learning Alcott proposed—observation and experience. I will describe remotely sensed Landsat data and EOSAT's position in the remote sensing industry; provide information about remote sensing satellites and the prospects for the future; and briefly outline the products and services being developed by EOSAT.

Remotely Sensed Landsat Data

Landsat data are acquired from satellites that orbit the Earth at 438 miles. Since the 1970's there have been five satellites in the series; Landsats 4 and 5 are currently operational and have been aloft since 1982 and 1984, respectively. Each satellite returns to the same geographic point at approximately the same local time every 16 days.



Reproduction of Landsat Thematic Mapper Image, acquired October 3, 1989. Image courtesy of EOSAT, Lanham, Maryland.

The data are acquired by electro-optical sensors that measure reflected and emitted energy from Earth. The Thematic Mapper (TM) sensors on Landsats 4 and 5 record reflected energy in six bands of the electromagnetic spectrum, from the visible to the short-wave infrared. Emitted (thermal infrared) energy is recorded in a seventh band. The six reflected-energy bands have a ground resolution of 30 meters (98 feet) and the thermal band has a resolution of 120 meters (394 feet). Each full scene (or frame) "looks at" a ground area approximately 110 miles by 110 miles in dimension. Since 1972 over 2.7 million scenes have been acquired by the satellites and are archived for use in comparing Earth's present with its past.

Because the data are digital, they are ideally suited for use in GIS applications. Information can be quickly and accurately derived from digital data using a desktop system and the appropriate software. The data can be oriented to a map projection and co-registered with other sets of information. The data are managed and distributed by EOSAT, which can also customize the data to get the needed level of accuracy for a particular analysis.

What is EOSAT?

EOSAT, formerly the Earth Observation Satellite Company, is a joint venture of Martin Marietta Astrospace and Hughes Aircraft Company. Headquartered in Lanham, Maryland, EOSAT was born out of the Landsat Commercialization Act, Public Law 102-365 in 1984. In addition to operating, maintaining, and managing the spacecraft and the ground receiving stations, EOSAT was awarded a contract to develop a broader market for Landsat's remotely sensed images of the Earth. The necessity to expose future generations of potential users to the beauty and power of digital images of the Earth's surface became obvious.

New legislation passed in 1992 enabled EOSAT to take a more innovative approach to marketing Landsat data, including pricing flexibility. EOSAT now markets low-cost Landsat data sets for educational use under the name "Scholar Series."

Because Landsat 6, the newest of the satellite series, met an early demise shortly after launch in 1993, EOSAT's role as the commercial provider of remotely sensed data changed significantly. To compensate for a potential lack of data, the company has undertaken agreements with additional sources of satellite data such as India, Russia, and Japan.

Educational Products and Services

Our low-cost Scholar Series is available on 3.5 inch or 5.25 inch diskettes. With a school site license, one purchase of a single data set enables the teacher to make copies for all systems, as necessary, within that school. Colleges are granted "departmental" licenses. Featured in the Scholar Series are data sets of Charleston, South Carolina, after Hurricane Hugo; Yellowstone National Park during the devastating fires in 1988; the Kuwait oil spill during the Persian Gulf War; Chernobyl, Ukraine, just days after the nuclear accident in 1986; and a Flood Study double-scene comparison of the Mississippi floods, acquired during the drought year of 1988 and the floods in 1993.

In addition to low-cost data availability, EOSAT provides instructional information for teachers by sponsoring cooperative projects to develop course curricula in primary, secondary, and university education.

One such project has been underway for over four years. The National Council for Geographic Education; EIDETIC Digital Imaging, a software development company in British Columbia, Canada; and EOSAT have developed lesson modules that are now available. When used in conjunction with the Scholar Series and PEDA/Geog image processing software, the program enables students to interact with actual images of Earth. Designed and tested by college and high school teachers in the U.S. and Canada, the modules continue to be tested and refined.

Students enjoy the interactive process of analyzing the images. Looking for roads, houses, farms, or bodies of water, and being able to recognize those physical features, is an exciting and rewarding

intuitive process. The image data sets are subscenes of the 300 megabyte full Landsat scenes, covering an area of 512 (30 meter) pixels by 512 pixels or approximately 9 miles by 9 miles.

In a cooperative effort with the National Center for Geographic Information and Analysis (NCGIA), EOSAT is a sponsor and member of the Steering Committee to develop a Core Curriculum in Remote Sensing. It is envisioned that this effort will result in a tool for university-level educators similar to the GIS Core Curriculum in scope.

To expand further the use of remote sensing in the classroom, we work around the world with programs such as the Jason Project (interactive television programs piped directly to classrooms) and the NASA Space Grant Consortia across the United States.

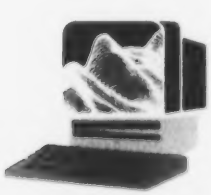
Remotely sensed images of the Earth are powerful, dynamic, and proven to be stimulating to children everywhere. Through the application of ever more affordable tools, this technology can be incorporated into the mainstream curricula. By doing so, we will provide our students with an exciting method to observe and experience, interactively, the application of their subject matter. EOSAT remains ready and willing to support teachers in their commitment toward one of our most valuable natural resources—our youth.

Information about EOSAT is available from EOSAT (see the section Resources for GIS in Education—Data Sources)

References

Alcott, A.B. in *Webster's Book of Quotations* (1992). New York: PMC Publishing Company, p 82.

Estes, J.E., et al. (June 1994). The NCGIA Core Curriculum in Remote Sensing. *PE & RS*, 945-948.



SimCity 2000

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OK, SimCity 2000 is not a true Geographic Information System. It is a game. However, it is a game with an incredibly rich and integrated system of geographic information. In SimCity 2000 you become Mayor, establishing and managing a simulated city, watching as it evolves, based on its own rules of urban interaction and development. Because of the sophistication of its design, and the fact that it can be so engaging for the kids and adults who play, SimCity 2000 offers tremendous opportunities for learning in: social studies, urban planning, science, math, politics, geography, and resource management. I believe that it can be a wonderful companion to more traditional tools of GIS.

Overview of SimCity

The SimCity 2000 User's Manual provides a good introduction to SimCity:

> When you play SimCity 2000, you become the planner, designer and mayor of an unlimited number of cities. You can take over and run any of the included scenario cities, or build your own from the ground up.
>
> You're in charge. You can choose to build small, rural towns, or huge bustling megalopolises. As you design and build your cities, simulated citizens, known as Sims, move in and build their homes, stores and workplaces, raise their families and invite their friends. If your city is a nice place to live, your population will increase. If it's not, your Sims will leave town. And be assured that they'll let you know what they think about you and your policies.
>
> SimCity 2000 is primarily a "building" game, where you create and try to increase the size of your cities — but you also have plenty of opportunities to destroy. From bulldozers to earthquakes to air crashes, the implements of destruction are only a mouse-click away. But remember, it's a lot more challenging to build than to destroy, and the lives, hopes and dreams of millions of Sims are in your hands.

To play SimCity, you begin with uninhabited wilderness. A map appears on the screen, showing a diversity of bare land, forest areas, flowing water, hills, and valleys. (You either design your own region, or you let the game randomly generate one for you.) The terrain is divided into tiny squares, called "tiles" (in essence, a grid-based GIS), with each tile representing one acre.

Your first task is to create three types of zones:

1. Residential — where the Sims will live
2. Commercial — where the Sims will shop and conduct business
3. Industrial — where the Sims will work

For example, you might want to have residential areas near the woods, but distant from the industrial areas to enhance the living environments. You might want to have commercial areas bordering the residential areas and near the river to promote commercial, rather than industrial, use of the waterways.

Before the Sims start to move in, you also need to establish a power network, with a power plant (coal, hydro, oil, or nuclear) and a grid of power lines connecting the plant with each of the zones. And you need to lay out some roads for the Sims to travel to work, home, or shopping areas.

Once you have done this, the magic starts happening (at least my students seem to think that it is magical). As you watch, homes start to appear in the residential areas, businesses appear in the commercial areas, and factories appear in the industrial zones. You notice that cars travel the roads, and, in general, the hustle and bustle of a growing city takes place in front of your eyes. The Sims have moved in and have started to occupy and develop the city.

As Mayor, you have the responsibility to manage the city's development, to balance factors such as police and fire protection, adequate schooling, a stable tax base, and a balance of residential, commercial, and industrial needs. You also need to be able to respond to disasters such as floods, fires, or tornadoes. And you need to monitor your own popularity, which is based on your ability to manage these complex interactions.

SimCity 2000 screen shot. Courtesy of MAXIS

As Mayor, you can add a number of variables such as more zones with different density levels; above- and below-ground means of transportation; a complex water system; airports and seaports; police and fire stations; and educational and recreational facilities.

Each change you make has an impact on the city. For example, adding police stations reduces crime, but increases taxes. Adding residential zones without adding transportation limits the rate at which Sims move in and occupy the area. And an imbalance among the three types of zones causes skewed development (such as high unemployment when there are more residences than jobs).

What is the goal of the game? As with managing any city, there is no single pre-determined goal. It all depends on what sort of city you want. You can manage for unlimited growth, or for stabilization at a particular size. You can manage for ecological sensitivity, maintaining broad spaces of forest land and parks, and promoting public transportation. Or you can manage for your own self-aggrandizement, always striving to increase your popularity rating and taking advantage of some of the perks of mayorhood, such as a mansion in a scenic part of town. These issues certainly sound familiar.

SimCity as a GIS

SimCity 2000 is not a typical GIS in that it is a simulation game, rather than a tool for spatial analysis of reality. You cannot import real data (except in an approximate sort of way). You cannot do standard GIS analysis (except in the pre-defined ways incorporated into the game). And I certainly would not want you to become mayor of my own city simply because you successfully managed a SimCity.

Nevertheless, SimCity is, in fact, a remarkable Geographic Information System. The power of SimCity 2000 as a GIS is that it brings the geographic information and analysis to life — it gives personality and character to the geographic and spatial analysis.

It also brings a finite but diverse set of variables and interactions into a unified whole: promoting an integrated, systemic view of geographic information, resource management, and urban planning.

From a GIS perspective, the "tiles," or tiny squares of SimCity maps, are the grid of a grid-based Geographic Information System. One unique aspect of this in SimCity is that the values in each tile change, based on an interaction with other tiles and with the overall system interactions. Tile values are neither static nor disconnected from their neighbors.

Another GIS concept is the stacking of tiles, which corresponds directly to the layers of a GIS. Again, because this is a simulation rather than a static representation, these layers interact in a causal and developmental fashion. Just as with a GIS, the map displays of SimCity 2000 enable us to examine the layers individually or as overlays, to better understand their inter-relationships.

The tools of spatial analysis at your disposal within SimCity are diverse. Some have direct counterparts in commercial GIS and some are totally unique to this game.

Map display—the displays show the development of the city. You can view your entire city from afar (comparable to a 3-D oblique orthographic view), zoom in for a closer look at any region, or rotate the image to get alternative perspectives.

Specialized maps—you can select one of several specialized maps (comparable to layer selections in GIS packages), such as structures, zones, roads, power grids, water system, population, crime and city services.

Graphs—these depict changes in selected values over time, such as population, education levels, industrial diversity, and traffic density.

Newspapers—every month (the basic unit of time for planning purposes), a new edition of the newspaper appears, keeping you informed of current events, new inventions, city developments, and public opinion polls.

Educational Value

Use of any tool in an educational situation must be based on clarity of educational goals; and there can be many for SimCity 2000. Most of my educational use of SimCity has either been learning through my own use or training teachers in workshops on map-related software. However, if I were back in the classroom my primary goals for using SimCity 2000 in, for example, an urban middle school situation, would be:

- experience with a computer game/simulation that goes beyond drill and practice or video war games
- awareness of and experience with issues in urban planning
- development of thinking and problem-solving skills
- familiarity with underlying design issues in SimCity 2000
- understanding of correlations with and differences from commercial GIS
- application of some concepts of SimCity 2000 to the students' own city
- having fun with SimCity, and the corresponding support for student engagement in the learning process.

To move toward these goals, I would begin with a brief introduction to SimCity 2000 and then let the students explore on their own, with guidance and support on an as-needed basis. I would let them proceed for several class sessions, balancing the student work with directed instruction in some of the key concepts, as the need and opportunity arose. Students would share their cities and some of the design and development issues with which they were struggling.

I would then start to make the linkages with issues in students' own environment, such as education, entertainment, crime, transportation. As much as possible the class would work on developing a better awareness of how these issues are dealt with in their own community. Urban planners, along with the Mayor or other city officials, would be invited to class.

Penultimately, the class would culminate in a class-wide preparation of a SimCity model of their own city, starting with the underlying geographical features, adding zones, transportation, and power corresponding as closely as possible to their city. Then individually or in small groups, the students would plan and implement development strategies for the SimCity simulation of their city.

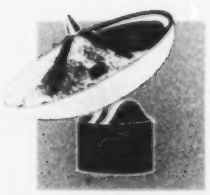
Ultimately, I would strengthen the linkage by encouraging students to get actively involved with actual urban planning, resource management, and the political agenda of their own city. In fact, I would probably stretch this activity into a several month or even full-year course, with SimCity as just one element in a multi-faceted urban studies program.

Information about SimCity 2000 is available from Maxis (see the section Resources for GIS in Education—GIS and other Mapping Software.)

References

Bremer, M. (1993). SimCity 2000 User's Manual. Orinda, CA: Maxis.

Dargahi, N. and Bremer, M. (1994). *SimCity 2000, Power, Politics, and Planning*. Rocklin, CA: Prima Publishing.



Editorials from the Participants

Reflections on the Conference

by Charlie Fitzpatrick

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It was a major step along a very promising course. For three days, educators, researchers, and GIS-oriented professionals gathered to talk about the possible role for GIS in pre-college education. Like most discussions of things educational these days, there was some consensus, a fair bit of disagreement, and universal passion for and about good education.

There seems to be widespread agreement that GIS will make its way into the mainstream of at least North American society. More and more, our lives will be affected by people needing to use the best tools available for making "resource-efficient decisions." (Efficient not just in dollars, but also in time, energy, materials, environment, labor, management, and, for lack of a better term, spirit.) This brings some exciting opportunities for education and an unusual challenge.

We want students who are careful and critical thinkers, passionate learners, effective problem solvers, integrators of knowledge, and group collaborators; students who can also explore new ground, investigate and develop their individual views and modes, and focus intensely on a single topic. Our hopes for students are high.

GIS can provide a vehicle in which to reach toward these lofty goals. Its promise—like that of music, literature, or art—lies in its capacity to be molded with infinite variety and complexity, shaped for unique situations.

But the challenge facing the use of GIS in education is formidable. Few teachers are comfortable with the concepts of GIS or the powers of spatial analysis. Few teachers would assert that their classroom provides a level of technological training that adequately represents what today's students will need in the decades ahead. Few teachers are equipped to teach in multiple disciplines to students of all learning styles and abilities. Few teachers have the time, opportunity, and encouragement to collaborate with their peers to produce the comprehensive, integrated, multi-year, multi-threaded learning package of their dreams.

The biggest challenge is that few teachers willingly embrace and implement in full scale fashion that which is unproved, unpredictable, and unfamiliar, where teachers and students may be on equally foreign ground. Geared by their own instruction to approach teaching and learning as a more step-by-step process involving at least a semblance of common experience, today's teachers are without a model on which to reflect. GIS—the use of sophisticated hardware and software, combined with extensive data sets and powerful analytical tools—marks the dawn of a new era. The models of yesteryear do not fit handily with the tools of tomorrow.

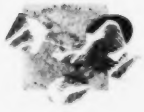
What seems needed is a new paradigm for teaching and learning. In an age when instant gratification through interactive media has become commonplace; in a world where problems and situations are more prominently investigated; and in a universe

experiencing a supernova of data and almost cancerous growth of access channels, a different way of encountering and coping with information seems to hold promise. When learning is more cumulative, integrated, and relevant to daily lives, and accomplished by exploring, finding "non-answers," exploring further, and finding relationships, students may perhaps develop more of their potential. When they can explore information and learn skills while interacting with others and crafting their own approaches, they will have a greater sense of ownership of their knowledge and capacities, and perhaps a greater commitment toward the world around them.

In such a setting, it is hard to predict the paths learning may take. This makes it hard to set timelines and hard to determine appropriate benchmarks of accomplishment. GIS projects rely on and promote synergy, where the whole is greater than the sum of the parts. The paths and routes may involve unanticipated channels; the results can be astonishing in their power.

It is this carrot which hangs before the vanguard of GIS-users in schools. Unfortunately, some pioneers must seek these visions in settings with precise demands and severe constraints. A few fortunate (or internally directed) souls have embarked on a shared adventure of learning—a true voyage of discovery—with their students. Focusing (in truest Olympic fashion) at least as much on the struggle as on the final product, these innovators will share in finding new information and ideas about their world and will model admirably the role of lifelong learner in a community of valued explorers.

The challenges in education today are significant, but not insurmountable. GIS is a powerful tool whose time has come. The required pieces of robust hardware, sophisticated software, and expansive data are all readily available. The remaining component in GIS is a thinking user, in a situation where the available powers may be fully engaged.



Issues in GIS in Education

by Terry Woronov

Terry Woronov was one of the organizers of the EdGIS Conference. A former research assistant at TERC, she studied issues involved in integrating GIS in pre-college classrooms. She is currently the Curriculum Director of a computer-based, integrated math/science/language arts project in Vermont.

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A geographer recently claimed that "'GIS fever' is sweeping geography" (King, 1991, p. 66). As we know from the EdGIS Conference, it is beginning to infect pre-college education as well. As an educational tool, GIS may help students ask questions, visualize data, and solve problems about their environment (Audet, et. al., 1993). "Any problem with a spatial component is a candidate for students to explore with a GIS" (Audet, p. 36).

While GIS is experiencing explosive growth in business and industry, it is still in its infancy in pre-college education. The push to incorporate Geographic Information Systems into schools is driven by the concept that there is a tremendous advantage in seeing information visually, rather than in tabular form (Tufte, 1990), and that GIS use increases students' knowledge and understanding of geographic concepts and spatial data. This, in turn, is predicated upon the assumption that through using GIS, students will learn spatial analysis and problem-solving skills. GIS technology does have tremendous potential as an analytic tool for geographic analysis (King, 1991). However, presentations at the EdGIS Conference, literature in the field, and personal experience working with GIS-using educators lead me to conclude that there are still many logistical, pedagogical, and technical issues to be resolved before students will be able to use GIS to gain a better understanding of the world around them. Incorporating GIS in education is complex; my premise is that it cannot be divorced from questions of implementing computer technology in schools, which in turn is merely a subset of the larger question of how to manage and implement change in schools.

GIS and Geographic Literacy

GIS is used in professional applications to perform spatial analyses. But before GIS can be transferred to schools, teachers and curriculum designers need to define clearly what that means. Not only must they identify what kinds of spatial analyses are appropriate for students at different levels, but also break down the task of spatial problem solving into its component parts. In trying to teach analytic and problem-solving skills, teachers tread a thin line to "make implicit understandings explicit, while struggling not to squeeze the life out by pinning it down with false precision" (Wiske & Houde, 1988, p. 196).

Explicitly teaching and scaffolding spatial problem solving will be central to successful integration of GIS in schools. This was made particularly clear in the pilot program Richard Audet and William Huxhold recently completed using GIS with high school students. At the outset, they assumed "that students had the ability to recognize real-life spatial problems and possessed the skills needed to solve them" (Audet, 1993, p. 37). They found that students worked well "with paper maps, a restricted set of data, and well defined questions" (p. 37). But when asked to

recognize spatial patterns in geographic data, the students attempted to solve the problem by "conducting an untargeted browse through the database" (p. 37).

Students' inability to formulate and resolve spatial problems raises the question of whether or not it is possible to teach students how to use GIS without teaching the geographic concepts that underlie the systems. Geographer Stephen Walsh argues that "to know GIS one must first know geography" (Walsh, 1992, p. 55).

Classroom practice

Integrating GIS into classroom practice is a complex process. As Kerr (1991) points out, it is necessary to understand "how teachers learn not only to use computers, but also to integrate them into the curriculum and the flow of classroom activities that realizes the curriculum" (Kerr, p. 122). In individual classrooms, teachers must match the computers and the software with instructional goals, the subject matter, the students themselves, and the context of instruction (Winkler, 1985).

Kerr asks several questions that help illuminate how teachers view technological innovation; programs successfully integrating GIS will need to address, and answer, each of these questions. The first and most important concerns how well GIS fits into existing pedagogy. For example, equipment constraints may require students to work in pairs or small groups, which may be new practice for some teachers. More significantly, if the goal of educational GIS use is to encourage students to solve spatial problems, then the effective use of the software may require a shift in pedagogical technique. Learning to solve problems and analyze data requires that students actively participate, by formulating and then discovering answers to their own questions. This methodology, helping students develop and defend their own ideas, is recommended practice by organizations such as the NCTM and AAAS in their standards and benchmarks, respectively. But these organizations recognize that this kind of teaching represents a profound change for many teachers: "Incorporating guided inquiry into standard secondary school courses requires a fundamental shift in educational paradigm" (Wiske & Houde, 1988, p. 214). Guided inquiry "entails fundamental changes not merely in technology, but in curriculum, in the social organization and management of the classroom, in teaching approach, and ultimately in basic beliefs about the nature of knowledge and the roles of teachers and learners" (Wiske & Houde, p. 216). Using GIS in classrooms may entail a willingness on the part of the teachers—and the students—to attempt new forms of learning.

Beyond the question of methodology, Kerr's second important question relates to classroom-level logistic issues. Logistics that are taken for granted in business and industry may create tremendous stumbling blocks for schools. For example, students may be required to go outside the school—or even the district—to collect data to input into a GIS. This is not a trivial problem when classes may be less than an hour long. Using GIS naturally also requires that adequate computer equipment be available for students' use, and if the students' investigations call for sharing or retrieving data over the Internet, they will also need access to an outside phone line. While these seem like simple questions, they can become tremendously difficult—and expensive—to implement in schools.

A third issue is related to how well GIS fits into the existing curriculum. Teachers need supporting curricular materials to help integrate GIS into the standard curriculum. To date, very few materials have been developed for teachers to use; the question of how to add GIS to existing classroom curricula has been the responsibility of any individual teacher who wanted to use the technology. A related, and not inconsequential, issue is time: teachers are under tremendous pressure to cover specified amounts of material during the school year. Accommodating GIS in their tight schedules mandates that the systems dovetail efficiently with the existing curriculum.

Kerr's final question involves evaluation. Before implementing GIS in education, we must understand what results are expected from the students, and how those results will be evaluated. For example, in GIS use, will students be evaluated on how much they have learned about the software? Or the quality of the data they have gathered and input? If teachers

intend to evaluate less tangible skills, such as students' increased ability to perform spatial analysis, then the curriculum must also clearly define how this skill can be demonstrated and measured.

Technical issues

Several immediate technical issues regarding GIS software must be addressed before wide-scale implementation can occur. As discussed at the Conference, the vast majority of GIS programs are not designed for the educational market. Interfaces, while becoming "less hostile" (Walsh, 1992), are cumbersome and less than intuitive, especially for new computer users. Documentation must be written that is appropriate for teachers and students with less GIS and technological background.

Beyond these basic issues, many of the technical issues and decisions that are taken for granted in the GIS industry are difficult to solve—or even to formulate—without a strong technical background or good understanding of the technology. For example, data on schools' local areas or other areas of interest may not be readily accessible. Teachers may not be aware of various data sources, nor have the funds available to purchase existing data sets. Additionally, schools may not have access to digitized maps, nor have the technical ability to make changes in base maps, should that be necessary for the purpose of a lesson.

Teachers must also address the question of data accuracy. GIS professionals understand that the accuracy of any map created with a GIS is a product of many different factors and that the final map will be a result of series of decisions and compromises on cost, effort, and data availability (Bernhardsen, 1992). Teachers, however, may not have the necessary technical background on which to base these kinds of decisions, thereby underestimating the difficulty of accurately gathering data and creating maps.

This leads to a final question regarding how much understanding teachers—and students—need to have about the underlying data structures in GIS. For example, the classroom I observed used MapInfo as their GIS, which requires that users identify the type of data being input on each layer (e.g., ratio, ordinal, nominal). If these terms are not clear to students, can the software still be used effectively? If students are gathering and inputting their own data into the GIS, how much should they know about setting up database structures? There is no one set answer to these questions, but awareness of the complexity of decisions involved in using GIS is important in understanding how it may be incorporated into classroom use.

Support

Regardless of how well thought out the conceptual and curricular framework might be, classroom realities frequently militate against successful integration of new technology. Logistics and support present formidable issue in implementing GIS in pre-college classrooms; before proposing wide scale adoption of GIS in schools, we need to look at both material and institutional barriers to change. Educational researchers concur that support is an essential factor in school change: "The more factors supporting implementation, the more change in practice will be accomplished" (Fullan, 1991, p. 67).

Financial support, of course, presents the first problem—for hardware, software, training, and materials. One research example highlights the critical nature of this issue: Based on data gathered in 1989, Becker predicted that by 1993 only three-fifths of the installed computer base in U.S. schools would be Macintosh or DOS platforms. The remaining equipment would consist of Apple II's and other 8-bit machines (Becker, 1991). Clearly, this then implies the need to extensively upgrade educational hardware before being able to integrate GIS into the curriculum.

Support, however, is much more than just money and equipment. "Lasting change will not occur simply by giving teachers the latest technological tools. Teachers must be provided with on-going support which is available only if the larger system in which they are working changes as well" (Sandholtz, et. al.,1991, p. 2). Training is essential, both in software use and in integrating GIS into the general curriculum. Facilities must be provided for technical support and professional development. Time needs to be made in teachers' schedules to be able to receive training.

GIS use may call for significant change in classroom practice. Teachers will need substantial collegial and administrative support to be able to implement these changes. Researcher Pat Cox summarizes the scope of support necessary: "Our findings suggest that school improvement efforts need support at two levels: assistance focused on the *content* of the new practice, directed at the teachers who are implementing the innovation; and assistance focused on the *context* of the new practice, aimed at securing the necessary approval, resources, facilities, and personnel to ensure continuation and institutionalization of the innovation" (Cox, 1983, p. 13).

Most educators, I believe, would agree with Tufte (1990) that envisioning information is a powerful tool—not only for designers and consumers of information, but for students as well. I also believe that computers can be powerful tools to motivate changes in schools (Kerr, 1991). Through allowing students to visualize, manipulate, and query large amounts of data, GIS can help create important changes in how and what students learn. We need to take into consideration the best ways to implement that change, and work to support teachers and school systems that are attempting innovations.

In the classic RAND study of factors that influence educational change, Berman and McLaughlin (1974) found that the most successful educational changes were ones that underwent what they call "mutual modification"—where both the innovation and the settings were changed in the course of implementation. The issues discussed above suggest several areas where schools and classrooms may have to change in order to integrate GIS. GIS use implies changes in classroom practice; requires high levels of technical expertise; and demands strong commitments to support at all levels of the school bureaucracy.

I think we also need to consider how GIS technology itself might change in educational settings. This implies first that software, interfaces, and documentation must become better suited for educational use. But real modification of the innovation in this case may also mean finding more creative applications. So far, we have assumed that students will use GIS in the same way and for the same ends as do GIS professionals in industry and academics. Perhaps we need to think of ways to accommodate alternate usages and new applications for GIS, ones specifically designed for student users. With attention to the special needs of students and teachers, GIS may eventually be successfully integrated into pre-college classrooms.

References

Audet, R., Huxhold, W., & Ramasubramanian, L. (1993). Electronic exploration: An introduction to the geographic information system. *The Science Teacher, 60*(10), 34-39.

Becker, H.J. (1991). How computers are used in the United States: Basic data from the I.E.A. computer in education survey. In M. Chen & M. Paisley (Eds.), *Children and Microcomputers*, Beverly Hills, CA: Sage.

Berman, P. & McLaughlin, M.W. (1974). *Federal programs supporting educational change, Vol. VIII: Implementing and sustaining innovation.* Santa Monica: The RAND Corporation.

Bernhardsen, T. (1992). *Geographic Information Systems.* Arendal, Norway: Viak IT.

Cox, P.L. (1983). Complementary roles in successful change. *Educational Leadership, 41*(3), 10-14.

Fullan, M.G. & Steigelbauer, S. (1991). *The new meaning of educational change* (2nd ed.) New York: Teachers College Press.

Kerr, S. (1991). Level and fulcrum: Educational technology in teachers' thought and practice. *Teachers College Record, 93*(1), 114-136.

King, G.Q. (1991). Geography and GIS Technology. *Journal of Geography 90*(1), 66-72.

Sandholtz, J.H., Ringstaff, C., & Dwyer, D.C. (1991). *The relationship between technological innovation and collegial interaction.* (ACOT Report # 13). Apple Computer, Inc.

Tufte, E. R. (1990). *Envisioning information.* Cheshire, CT: Graphics Press.

Walsh, S.J. (1992). Spatial education and integrated hands-on training: Essential foundations of GIS instruction. *Journal of Geography, 91*(2), 54-61.

Winkler, J.D., Shavelson, R., Stasz, C. & Robyn, A.E. (1985). Pedagogically sound use of microcomputers in classroom instruction. *Journal of Education Computing Research, 1*(3), 285-292.

Wiske, M.S. & Houde, R. (1988). From recitation to construction: Teachers change with new technologies. In Schwartz, J., Yerushalmy, M. & Wilson, B. *The Geometric Supposer: What is it a case of?* Hillsdale, NJ: Erlbaum.

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Enhancing Environmental Education

by M. Duane Nellis

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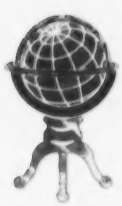
To enhance environmental education (including geographic education) as we approach the next century, we must explore a series of reforms that force us to re-think our traditional systems of learning. A first reform involves the need for greater consensus about the learning and teaching of environmental education and geography. The EdGIS Conference and the development of national education standards in selected disciplines are examples of the emergence of a consensus related to learning needs. A second reform is related to the integration of technology into environmental and geographic education. The availability technology and the growing opportunities for using it (particularly GIS) in understanding environmental patterns and processes reflect an awareness of the need for technology in the learning process. Lastly, reforms must be implemented that bring about change in curriculum and educational learning strategies through the development of exemplary curriculum materials.

Related to the last of the above reforms, a series of high quality GIS technology-based curriculum modules and implementation strategies must be developed at a range of grade levels. Obstacles, such as lack of teacher training, limited availability of user-friendly software, and competition for use of computers with other curricula, must be overcome. With the wealth of information and the integration of information associated with a GIS, technology is a natural link to understanding spatial processes and, with that, to comprehend more fully environmental systems.

To strengthen interest in GIS among educators, opportunities for utilizing remote sensing techniques should be linked with GIS. Remote sensing, particularly in the form of satellite data, provides teachers and students with greater enjoyment than do some other forms of visual aids, thus enhancing student retention of information. Remote sensing also allows the examination of broad relationships among earth features at a previously unavailable synoptic scale. In addition, data can be obtained sequentially, thereby providing a pattern of environmental change over time, which assists in understanding natural and human-induced change.

Computers are found in more and more classrooms, and a larger and larger proportion of children have access to computers at home. At the same time, free data and software are rapidly becoming available for a large range of applications. As we look to the future, hardware and software are becoming increasingly invisible, so that the emphasis can be placed on problem solving as it relates to environmental education.

To fully capitalize on GIS for enhancing environmental education, we must (1) develop exemplary curriculum materials, (2) set up a series of teacher mentors (master teachers) who can facilitate training of other teachers on GIS capabilities, (3) develop data standards to facilitate easy transfers of data for educational use, and (4) pursue funding opportunities with federal agencies and private corporations to facilitate diffusion of GIS-based curriculum materials. Through these efforts, improvements in learning appear promising.



Defining GIS — A Note of Caution

by Kay E. Weller

Dr. Kay E. Weller is Assistant Professor of Geography at the University of Northern Colorado, where she teaches geography and secondary geography methods. Her dissertation research at Kansas State University focused on the appropriateness of GIS in grade 6.

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fax: (303) 351-2890

Some concerns should be raised regarding Geographic Information Systems as presented at the EdGIS Conference. GIS is not an easy tool to manipulate and use. In our enthusiasm about the possibilities for implementing GIS in the curriculum, we must be cautious not to mislead those teachers eager to provide additional tools for students. Teachers must be offered appropriate inservice situations to learn the powerful opportunities that GIS, as well as other technologies, can bring to their classrooms. Developers of educational technology must provide teachers with a product that is simple enough to learn in inservice sessions but powerful enough that students are able to analyze real life situations.

At the EdGIS Conference, the term GIS was applied so broadly that it encompassed more than GIS, to include mapping packages. Many powerful software packages have some of the elements of GIS, but few have all. For example, Fastcad is a database software with mapping capabilities; however, it does not have an analysis component. Confusion seems to exist regarding GIS as simply the layering and mapping of data using a computer. We forget that GIS includes the analysis component. For example, students using GIS with data pertaining to soils, hydrology, and proposed industrial location can map the effects of industrial waste on surface water for a particular location. They can look at several locations and determine the most appropriate place for the industrial facility based on the analysis capability of the software.

If GIS is to be interpreted more broadly, then perhaps the Conference should consider attaching a different name that would include not only GIS but other powerful mapping packages. In addition, it would be appropriate to have a definition of GIS that is straightforward and easily understood by the general public. Without an accurate definition and conception of what GIS is, teachers and students may not develop an accurate perception of the technology.

New Interface Technologies

Dr. Richard A. Bolt is a Senior Research Scientist at the MIT Media Laboratory at the Massachusetts Institute of Technology. He directs the Advanced Human Interface Group, which explores multimodal natural dialog involving speech, gesture, and gaze as input to computer systems and as a way to make computers more "people literate." He holds a Ph.D. in experimental psychology from Brandeis University.

by Richard A. Bolt

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Cambridge, MA 02139

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e-mail: bolt@media.mit.edu

In her remarks at the EdGIS Conference, Nora Sabelli of NSF asked rhetorically what might be the impact of the application of advanced technologies to GIS, and specifically, what might change conceptually due to such technologies.

A number of conference attendees stressed the use of simple, currently available interfaces. This view would argue for a focus on the keyboard and mouse as the main input and interactive tools. (These are also the interface tools that kids are likely to have on their home computers.) However, other conference attendees noted that technologies change and that new ones emerge, and argued that educators ought not plan in advance using the conceptual framework of today's commonly available technologies. Given the rate of technology development in computers and computer-related areas, to plan for today's technologies is to plan for yesterday. Perhaps a dual outlook is indicated, one that exploits today's ubiquitous keyboard and mouse ensemble and explores how these can most effectively be used, and another "advanced technology" track wherein new interactive devices are explored to see what unique advantages they may offer.

Interface devices that have reached a degree of maturity and robustness to be readily incorporated into interfaces employable in the field (read: the classroom) include: trackballs, tablets, gloves, speech recognition, 3-D cursors, track-balls. While these technologies are sturdy enough to take into the classroom, the new possibilities they offer may not be well understood.

For instance, some currently available tablets come with pressure-sensitive styli. This feature could be exploited, where pressure modulates which of several layers of geographically overlain data becomes visible, such as rainfall over the last half-century or decade; the harder you press, the deeper into the past you go. Or the pupil uses varying pressure to manipulate degrees of transparency, exploring sound overlays on maps, and so forth. However, some styli may be tricky for younger hands to manipulate deftly enough to make fine distinctions.

At least one version of gesture-sensing technology is probably child-proof enough to survive vigorous classroom use, namely the "PowerGlove" by the Mattel toy company. It is a video game adjunct which supports a direct interaction kind of interplay that might be especially attractive to younger kids.

Speech recognition is available in several forms, most notably for the recognition of discrete speech (where a short pause is introduced between the utterance of each word) and where the system is speaker-independent. The level of recognition is good enough to risk in a classroom setting, and the sheer novelty of being able to speak to a machine is sure to attract kids willing to experiment with it. Talking your way around, e.g., "Go north...more to the west..."

can be intriguing. Consider games where you utter the capital of countries, and the location lights up, and perhaps highlights of the city are shown.

Some of these, and other, technologies have reached the point of sufficient development to be incorporated into GIS interfaces, at least in an experimental setting. Less well-developed technologies, in terms of being ready to turn loose in the classroom, include touch screens, speech recognition, and gesture recognition by glove. Here it is a matter of degree. Certain touch screen technologies, e.g., an edge-mounted matrix of infrared beams which you break with a finger, probably can stand up to hard everyday usage. Certain kinds of plastic sheet overlay technologies can stand up to everyday usage in milieus of sticky fingers, jabs by pencil points, etc., but other types of overlay touch screens are not so durable. Some types of glove gesture-sensing technologies more sophisticated than the Mattel PowerGlove mentioned above can offer striking new possibilities for grasping and manipulating data in 3-D. However they tend to be both very expensive and fragile, as well as requiring sophisticated software and constant tuning and maintenance.

The development of robust software support is needed to control these devices. Decisions must be made carefully about how the degrees of freedom offered by any device can most effectively map to the geographically based material. A sub-issue here is what is known in human factors engineering as "response compatibility." Plainly put, how well does the physical action to be performed via some device accord with the intention to be expressed. An example of poor response compatibility is operating a flight simulator program by pressing certain keys on a keyboard; a better example is operating the flight simulator with a joystick.

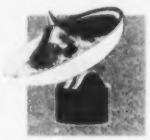
On the output side, larger projection screens in place of or in addition to desk-top monitors might be considered. More commodious display screens would better lend themselves to team exploration and learning than small size screens. Three-D sound as a spatial cue can be an interesting form of data fusion, supplying redundant location cues in the context of large screen displays, and especially in dynamic 3-D image surrounds. Opportunities for unconventional map types include sound maps whereby one navigates by means of distinctive "landmark" sounds (church bells, open air markets, tunnel roar), smell maps wherein bakeries and tire-repair shops provide the landmarks, and touch maps that are literally "hands-on."

Development of computer-based interactive milieus and evaluation go hand in hand. Perhaps a good deal of development could best occur through the local teachers and teacher groups working directly with the vendors themselves, leveraging entrepreneurial energies and professional insights to hone better products. Also needed is well-planned research on the impact and utility of certain types of interaction with information, and their implications for learning and cognitive growth generally. For example, interactive computer-based technologies offer such specialized milieus as flight simulation, virtual reality, or role-playing games. A leading question here is how various "virtual reality" settings might aid spatial cognition and geographic knowledge through offering active participation in a virtual environment presented in graphics and sounds.

Some styles of interaction may well be associated with high arousal, making it very attractive to some (though perhaps not all) kids, but not very conducive to either spatial learning or retention of material. Kids deeply engaged with a "shoot-'em-up" style game with monsters in a maze of underground caverns may over time become very familiar with the twists and turns of the enemies' lair, a type of incidental learning accompanying high arousal. But what kind of spatial knowledge do they carry away from the game? Have they learned the layout of the lair? Are they reacting to immediate and local cues without an overall sense of where things are? Are the best remembered spots those where a "battle" occurred? How well are spatial layouts assimilated in the context of high-arousal games in contrast to a slower, more cerebral than visceral, "quest" game where the progress depends more upon reasoning than reaction-time?

These are just a few of the tools and technologies that future GIS software can use advantageously to enhance its power, impact, and ease of use.

Enhance Educational GIS with Hypermedia and Local DataBases



by Derek Thompson

Dr. Derek Thompson is Professor of Geography at the University of Maryland and has taught about GIS at beginning to advanced levels. Developer of a laboratory of computer mapping and spatial analysis at the university, he is also exploring multimedia and hypermedia technologies and concepts for improving undergraduate geographic education.

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I write this opinion piece as a teacher of geography, well versed in the use of computers for geography education, both Geographic Information Systems and hypermedia. My editorial comments are focused on two themes: a belief in the need to exploit several computer technologies at one time, not simply GIS; and the need to consider seriously the cooperative development of local area pedagogically-oriented geographic databases.

Over the past few years the map and spatial analysis-oriented GIS technology has received a lot of attention, and, indeed, the EdGIS Conference emphasized this. To my mind, though, this could have been balanced by a greater presence at the conference of the more cognitively oriented hypermedia technology. I have seen Hypercard used enthusiastically in secondary social studies education more than I have seen GIS. This characteristic is not simply a result of software availability or teacher awareness, but also reflects a document-oriented humanistic tradition of social studies (compared to an analytical tradition in the physical sciences) that I believe is worth encouraging. I would like to see efforts directed toward the design of a teaching-oriented tool kit that blends the hypermedia and GIS approaches.

It has been my experience that teaching in geography and other fields frequently draws effectively upon a local area for examples and to provide experiential learning opportunities for students, kindergarten through college. I saw the local orientation in Randy Raymond's efforts (see "Urban Environmental Education in Detroit"), yet I did not see much at the EdGIS Conference about public sector local databases. Perhaps because the federal government has done more to distribute geographic data at modest cost, particularly NASA, EPA, NOAA, we have numerous resources available for global or continental scale studies. Yet I think that most citizens will never need to access global data; they will at some point in their lives consult local data sources. So in this regard I would like to see more attention to the establishment of partnerships of school systems, universities, and local governments for the creation of local database resources that could be exploited for pedagogic purposes.

One of my goals is to promote effective collaboration between higher education and primary and secondary education teachers and school authorities in establishing resource laboratories with clearinghouse function. They would serve as testbeds for trials of software and the development of

curriculum materials, founded upon a rich local area GIS database that could be used for teaching many subjects. In this context the map/spatial analysis and hypermedia-oriented toolboxes could be exploited jointly rather than separately. I believe too that curriculum enhancements can be more effective if teachers can get or assist in creating such cognitively-oriented materials that go beyond the rather static global electronic atlases prevalent today.

Editorial on Conference Recommendations

by Richard Audet

Dr. Richard Audet is a Research Assistant Professor in Science Education at Boston University and serves as a Science Resource Specialist in the Boston University Partnership with the Chelsea, Massachusetts, Public Schools. His dissertation research investigated the problem solving styles of novice users of GIS.

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e-mail: audet@asc.bu.edu

David Ausubel, a noted cognitive scientist who developed some important ideas about the connection between learning and conceptual change stated, "If I had to reduce all of educational psychology to just one principle I would say this: The most important single factor influencing learning is what the learner already knows. Determine this and then move forward." This statement can easily be paraphrased for our purposes. We might say, "The most important single factor... necessary to develop a rationale for using GIS as an educational tool...is to determine what we already know about GIS and education. Determine this and move forward."

In this light I would propose several immediate tasks.

1. Define the state of the art. Teachers who already are using the technology need to be identified and interviewed. They have already traversed much of the terrain. They know the minefields and can articulate the possibilities for the technology.
2. Complete case studies of a sample of the learners in these classrooms. What does GIS provide them that other learning approaches seem to lack in sufficient quantity? The information obtained from this population gives us the knowledge base from which to proceed. I envision using this information as one of the components of a GIS in Education (EdGIS) Sourcebook. As part of our effort to define the state of the art, we need to publish curriculum materials, names of vendors, available resources, etc.
3. Curriculum experts drawn from numerous subject areas need to be convened to identify areas where GIS is applicable to existing curriculum and possibly important to the curriculum of the future. This provides a detailed, subject-specific rationale for inclusion of GIS in the schools.
4. Convene applications development teams to develop GIS-based materials. Such groups would include but not necessarily be limited to, teachers, professional educators from schools of education, subject matter experts, GIS experts, curriculum development specialists, students, and parents.

When and only when this happens should we expand our efforts to include a significant number of teachers. If we don't do this with considerable forethought, will have the technology in place with little sense of how it can be used to its greatest advantage.

If my notes are accurate, Margaret Cozzens opened the conference with three observations that might guide our work.

- GIS is at the forefront of technological applications
- GIS expands the reach of educational opportunities
- Research and education are inseparable.

Gerhard Salinger posed a question that must be answered. He asked, "What is the learning that GIS allows that other ways do not?" Nothing less than a full answer to this question will suffice.

Reference

Ausubel, D.P. (1968). Educational pyschology: A cognitive view. New York: Holt Rinehart and Winston.

Resources for GIS in Education

Organizations

These organizations can provide valuable advice and support materials. Most notable among these is the National Center for Geographic Information and Analysis (NCGIA), which serves as a national research center and clearinghouse for GIS in general, and educational applications in particular. Also of special interest is-the electronic networking available through the EdGIS Internet "ListServ." By subscribing, as detailed below, you will join the e-mail sharing of materials and discussion of important aspects of GIS in education. Most of the organizations listed below were represented at the EdGIS conference, so you can find more detailed descriptions of their work elsewhere in this conference report.

EdGIS

c/o TERC
2067 Massachusetts Ave.
Cambridge, MA 02140
(617) 547-0430
contact: Daniel Barstow; dan_barstow@terc.edu

To subscribe to the EdGIS listserv:
send the Internet message "subscribe edgis" to
Majordomo@terc.edu

Ask about:

- EdGIS ListServ and other Internet services
- Educational curriculum and other GIS initiatives

National Center for Geographic Information and Analysis (NCGIA)

NCGIA-Santa Barbara
University of California at Santa Barbara
3510 Phelps Hall
Santa Barbara, CA 93106-4060
(805) 893-8224
Contact: Steve Palladino, (805) 893-4305,
spalladi@ncgia.ucsb.edu

NCGIA-Buffalo
Dept of Geography
State University of New York at Buffalo
105 Wilkeson Quad
Amherst, NY 14261
(716) 645-2722
Contact: Barbara Buttenfield,
geobabs@ubvms.cc.buffalo.edu

NCGIA-Maine
University of Maine at Orono
5711 Boardman Hall
Orono, ME 04469
(207) 581-2143
Contact: Kathleen Hornsby,
kathleen@mecan1.maine.edu

Ask about:

- NCGIA Secondary Education Program
- NCGIA Core Curriculum in GIS
- NCGIA Core Curriculum in Remote-Sensing
- GIS in the Schools: Workshop Resource Packet
- African Data viewer
- Other technical reports

American Association for the Advancement of Science

1333 H St. NW
Washington, DC 20005
phone: (202) 326-6666

Ask about:

- Project 2061—Benchmarks for Science Literacy

National Council for Geographic Education

IUP
16A Leonard Hall
Indiana, Pennsylvania 15705
(412) 357-6290

Ask about:

- K-12 Geography: Themes, Key Ideas and Learning Opportunities (guidebook)
- Software Materials list

National Geography Education Standards Project

Anthony R. de Souza
Project Executive Director
1145 17th Street, NW
Washington D.C. 20036-4688
(202) 775-7832
or (412) 357-6290 for Geography Standards

Ask about:

- "Geography for Life" (National Geography Education Standards)
- Other geography education materials and services

National Science Education Standards Project

2101 Constitution Ave, NW HA 486
Washington, DC 20418
(202) 223-1399
scistnd@NAS.bitnet or scistnd@NAS.edu

Ask about:

- National Science Education Standards Project

National Science Foundation

4201 Wilson Boulevard
Arlington, VA 22230
(703) 606-1614

Ask about:

- Instructional Materials Development grant programs
- Teacher Enhancement grant programs
- Other GIS and science initiatives

National Science Teachers Association

1840 Wilson Blvd.
Arlington, VA 22201
(703) 243-7100

Ask about:

- science education materials

GIS and Other Mapping Software

Listed below are the GIS and other mapping software packages that were represented at the EdGIS conference. Most are described in more detail in the GIS software section of this report. The list also includes several mapping software packages which lack the data import or analysis capabilities of "true GIS," but which do incorporate computer-based maps in a powerful educational context.

Accu-Weather Forecaster

Accu-Weather, Inc.
619 W. College Ave.
State College, PA 16801
(814) 237-0309

Ask about:
- Accu-Weather Forecaster (for weather data)
- Accu-Data (data service)
- Weather Education Poster & Modules

Alice Network Software

Alice Project
TERC
2067 Massachusetts Ave.
Cambridge, MA 02140
(617) 547-0430
contact: Alan Feldman; alan_feldman@terc.edu

Ask about:
- Alice Network Software (for students to share and analyze data)
- Network Science Handbook
- joining ongoing network science projects

ArcView

Environmental Systems Research Institute (ESRI)
380 New York St.
Redlands, CA 92373
(800) 447-9778
Contact: Charlie Fitzpatrick, (612) 454-0600

Ask about:
- ArcView, ArcInfo and other related products (vector-based GIS)
- ArcSchool Reader (newsletter)
- Adopt-a-School (discount pricing program)
- ArcData (catalog of data)
- Annual Arc/Info Map Book

GAIA

Island Institute
60 Ocean St.
Rockland, ME 04841
(207) 594-9314

Ask about:
- GAIA software (for remote-sensed images)
- educational products and services

GeoPoint

401 China Basin St., Suite 200
San Francisco, CA 94107
(415) 957-1560

Ask about:
- GeoPoint software

GEOSCOPE

LMSoft
1280 Bernard St. West #401
Outremont, PQ
Canada H2V 1V9
(514) 948-1000

Ask about:
- GEOSCOPE software (for remote-sensed images)
- educational products and services

IDRISI

IDRISI Project
Graduate School of Geography
Clark University
950 Main St.
Worcester, MA 01610-1477
(508) 793-7526
idrisi@ollie.clarku.edu
contact: John Auble

Ask about:
- IDRISI software (grid-based GIS)
- Explorations in Geographic Information System Technology
- educational support materials

Map Info

One Global View
Troy, New York 12180
(800) 327-8627

Ask about:
- MapInfo (vector-based GIS)
- data sources

National Geographic Society Kids Network

National Geographic Society
Educational Services
1145 17th St. NW
Washington, DC 20036-4688
(800) 368-2728

Ask about:
- NGS Kids Network (curriculum with student data exchange)
- educational materials catalog

SimCity 2000

Maxis
2 Theater Square
Orinda, CA 94563-3346
(510) 254-9700

Ask about:
- SimCity 2000 (software game)
- Teacher's Guide

Data Sources

Data are in many ways the central defining aspect of GIS in education. The data you use define the domains of the educational applications, and vice-versa. Most GIS software packages include some base maps and sample data. To go beyond this, there are several potential sources:

***USGS** — in a category of its own as a major source of map data*

***Other federal agencies** — as listed below, providing current and archival data*

***State and local agencies** — often have GIS data which schools can use, at little or no cost*

***Data vendors** — directly or indirectly affiliated with the GIS software company*

Data from each of these sources are usually available either on CD-ROM or downloadable via Internet. GIS data can require sizable storage space, hence the use of CD-ROMs as a prime medium for storage and delivery.

An important issue with data is format standards. Some data will directly import into your particular GIS package, some may need translation, and some just may not work with your package. This is currently a significant challenge for effective educational applications. However, GIS data standards, such as the Spatial Data Transfer Standard, are emerging and may alleviate this problem in the future.

This is a rapidly changing field, with new data sources appearing frequently. Some of the contact information provided may also change, but a call or e-mail message should connect you with current sources and currently available data.

United States Geological Survey (USGS)

Reston - ESIC
507 National Center
Reston, VA 22092
(703) 648-6045
(800) USA-MAPS—for state and regional Earth Science Information Centers (ESIC)

Ask about:

- Earth Science Information from the US Geological Survey
- Sources for Digital Spatial Data and Cartographic Software
- State Information Sources
- Manual of Federal Geographic Data Products (from the Federal Geographic Data Committee (703) 648-5755)
- GIS poster
- US GeoData Sampler
- Digital Chart of the World
- Digital Line Graph
- Digital Orthophotos
- many other digital maps and data sources

Earth Observation Satellite Company (EOSAT)

4300 Forbes Boulevard
Lanham, MD 20706
Contact: Anthony Shupin (908) 603-9595

Ask about:

- LandSat images and data sets
- Landsat Thematic Mapper Imagery - Charleston, SC (free poster)
- Scholar Series
- PEDA/Geog software
- Geo/SAT student programs

Environmental Protection Agency

Assessment and Watershed Protection Division
(4503F)
401 M St. SW
Washington, DC 20460
Contact: Alice Mayio

Ask about:

- National Directory of Volunteer Environmental Monitoring Programs

Joint Education Initiative

Office of Technology Liaison
4312 Knox Road
University of Maryland
College Park, MD 20742-5121
(301) 405-2324
jei@earthsun.umd.edu
contact: Bill Johnson

Ask about:

- JEI 3-Disk CD-ROM set

Long-Term Ecological Research Network (LTER)

LTER Network Office
University of Washington
College of Forest Resources AR-10
Seattle, Washington 98195
(206) 543-4853
Office@LTERnet.edu

Ask about:

- National Research Sites
- Electronic Networking and Data Management
- Remote-Sensing and GIS Laboratory

National Aeronautics and Space Administration

Contact the Regional Teacher Resource Center nearest you:

AL—Alabama—(205) 544-5812
CA—Ames—(415) 604-3574
CA—Dryden—(805) 258-3456
CA—JPL—(818)354-6916
FL—Kennedy—(407)867-4090
MD—Goddard—(301) 286-8670
MS—Stennis—(601) 688-3338
OH—Lewis—(216) 433-2017
TX—Johnson—(713) 483-8696
VA—Langley—(804) 864-3293
VA—Wallops—(804) 824-1176

Ask about:

- NASA Teacher Resource Center Network
- Guide to NASA Online Resources (Internet—gopher://naic.nasa.gov/Guide to NASA Online Resources)
- NASA SpaceLink
- Mission to Planet Earth (multi-faceted program)
- Other data resources

National Climatic Data Center

Federal Building
37 Battery Park Ave.
Asheville, NC 28801-2733
(704) 271-4800

Ask about:

- Local Climatological Data (CD-ROM)
- Cooperative Observers Climatological Observations

National Geophysical Data Center

NOAA
325 Broadway
Boulder, CO 80303
(303) 497-6826
internet: info@ngdc.noaa.gov

Ask about:

- Global Change Educational Diskette Project (PC diskette)
- Geophysics of North America (CD-ROM)
- Global Ecosystems Data (CD-ROM)
- Global Vegetation Index (CD-ROM)
- Mosaic home page (Internet—http://www.ngdc.noaa.gov/ngdc.html)

National Oceanic and Atmospheric Administration

Environmental Information Services
Universal Building Room 506
1825 Connecticut Ave. NW
Washington, DC 20235
(202) 606-4561

Ask about:
- NOAA Environmental Services Data Directory
- Earth System Monitor (magazine)
- Guide to NOAA Nautical Products and Services
- refer also to national data centers listed

National Oceanographic Data Center

User Services Branch
NOAA/NESDIS E/0C21
1825 Connecticut Ave., NW
Washington, DC
(202) 606-4549
services@nodc.noaa.gov

Ask about:
- Global Ocean Temperature and Salinity Profiles (CD-ROM)
- NOAA CoastWatch (Internet)

US Census Bureau

Bob Hammond
hammond@info.census.gov
(301) 763-1011

Ask about:
- Annual population data
- TIGER (Topologically Integrated Geographic Encoded Reference)

US Dept of Agriculture/Soil Conservation Service

National Cartography and GIS Center
South National Technical Center
501 Felix St., Bldg. 23
PO 6567
Fort Worth, TX 76115
(800) 672-5559

Ask about:
- National Resources Inventory
- Many other types of data

US Fish and Wildlife Service

Division of Information Resources Management
Branch of Field Operations
PO Box 25207
Denver, CO 80225
Alan R. Fisher, National Data Administrator for US Fish & Wildlife
(303) 275-2400

Ask about:
- US Fish & Wildlife WWW server (Internet — http://www.fws.gov)
- National Wetlands Inventory WWW server (Internet — http://www.nwi.fws.gov)
- Other data in process of development

US National Biological Survey

Sam Droege
MS 3660
1849 C St. NW
Washington, DC 20240
(202) 482-3925
DroegeS@mail.fws.gov

Ask about:
- Breeding Bird Survey
- Christmas bird count data
- Amphibian survey
- Other data in process of development

United Nations Environment Programme (UNEP)

Infoterra Programme Activity Centre
PO Box 30552
Nairobi, Kenya
011-254-2-62-12-34
spencerl@unep.no

Ask about:
- Infoterra
- Global Resource Information Database
- Global Environmental Monitoring System

Urban and Regional Information Systems Association (URISA)

900 Second St., NE, Suite 304
Washington, DC 20002
(202) 289-1685

Ask about:
- GIS—Government Information Solution (video)

World Resources Institute

1709 New York Ave., NW
Washington, DC 20006
(202) 638-6300

Ask about:
- World Resources 1994-95 (Book)
- World Resources 1994-95 Data Base Diskette (PC diskette)

EcoLinking—Everyone's Guide to Online Environmental Information

Book by Don Rittner
Publisher: Peachpit Press, Berkeley, CA
(510) 548-4393

Data through GIS software companies

Contact the vendor of your GIS software to inquire about data that are provided with the GIS package, additional data that the software vendors market or provide directly, and references for other commercial or governmental sources of data. One especially good reference to data sources is ArcData, as listed below.

ArcData

Environmental Systems Research Institute (ESRI)
380 New York St.
Redlands, CA 92373
(800) 447-9778
Contact: Charlie Fitzpatrick—612-454-0600

Ask about:
- ArcData (catalog of data)

Local Data Sources

Contact your state and local governments to inquire about sources for GIS base map and data of your local area. Also contact regional agencies, such as those supporting water and electric services. Many of these agencies have extensive GIS data which they can provide free or at modest costs for schools and other nonprofit organizations in their service area. Also, several states have established coordinating committees relating to GIS. A little searching can find a wealth of data resources.

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